HYDROSTRATIGRAPHY
OF THE ORG-393 CORE HOLE
AT ORANGEBURG, SOUTH CAROLINA

STATE OF SOUTH CAROLINA
DEPARTMENT OF NATURAL
RESOURCES

LAND, WATER AND
CONSERVATION DIVISION

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HYDROSTRATIGRAPHY OF THE ORG-393 CORE HOLE AT ORANGEBURG, SOUTH CAROLINA

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ABSTRACT

Hydrostratigraphic units of the South Carolina Coastal Plain are delineated by using hydrological, lithological, geophysical, and paleontological data from a continuously cored borehole at Orangeburg, S.C. Aquifers are 70 to 284 feet thick and, in ascending order, comprise the McQueen Branch, Crouch Branch, Gordon, and Upper Three Runs. They consist of quartz sand and impure limestone beds of Upper Cretaceous through Oligocene age. Confining units are 25 to 179 feet thick and, in ascending order, comprise the informally named Gramling and the previously named McQueen Branch, Crouch Branch, and Gordon. They consist of interbedded sand and clay, marl, and cemented sandstone and limestone beds of Upper Cretaceous through Eocene age. Hydrogeologic sections illustrate the thickness and lateral continuity of the units in Orangeburg County. Relationships between hydrostratigraphic and stratigraphic units at Orangeburg and the Savannah River Site in Barnwell County to the west are examined.

INTRODUCTION

During the period from 1995 to 2000 the South Carolina Department of Natural Resources (SCDNR) and the U.S. Geological Survey (USGS) collaborated on a drilling project and scientific study to collect much-needed subsurface data and to reevaluate the stratigraphy of the South Carolina Coastal Plain. A total of 19 core holes were drilled and more than 10,000 ft (feet) of core was obtained. Sixteen monitor wells were installed, about 700 paleontological samples were analyzed, and over 90 geophysical logs were made. The project was not completed, owing to a change in research priorities at the USGS. Although voluminous amounts of data were collected and analyzed, few reports were written. Scientists originally involved in the project had other obligations and several have since retired. This is the first of what will, expectedly, be a series of reports that will examine the hydrostatigraphic framework of the Coastal Plain in light of some of these previously unpublished data obtained from the core holes.

Two of the core holes were drilled in the Coastal Plain province in Orangeburg County, S.C., by the U.S. Geological Survey's Eastern Earth Surface Processes Team drill crew: Core ORG-393 was drilled in the spring of 1997 and core ORG-430 was drilled in the spring of 1999, both near the north edge of the city of Orangeburg (Fig. 1). The holes are located on the grounds of Clark Middle School at latitude 33º 30′ 29″ N and longitude 80º 51′ 54″ W. Land-surface elevation at the site is +253 ft msl (feet above mean sea level) as determined from altimeter measurements, using a local benchmark as the datum. ORG-393 was continuously cored to a depth of 1,138 ft and ORG-430, located about 10 ft from ORG-393, was continuously cored to a depth of 330 ft in order to recover samples from missing intervals in ORG-393 and to minimize possible microfossil contamination from drilling mud. The cores are stored (March 2007) at the South Carolina Geological Survey's core repository at 5 Geology Road, Columbia, S.C.

Core ORG-393 penetrated 1,116.5 ft of poorly consolidated Cretaceous and Cenozoic sediments of the Southeastern Coastal Plain hydrogeologic province and 21.5 ft of consolidated sedimentary rocks of the Piedmont hydrogeologic province. Hydrostratigraphic units delineated from the core are described herein, and hydraulics data are provided where available. Reported footages are relative to land surface unless otherwise noted, and boundaries of hydrostratigraphic units are reported to the nearest foot.

PREVIOUS WORK

No continuous cores had been obtained from boreholes in Orangeburg County prior to the drilling of ORG-393. Siple (1975) provided the most comprehensive ground-water study of the county, analyzing hydrogeologic data from several hundred wells. Colquhoun and others (1983) presented lithostratigraphic sections that traverse the county. Aucott and others (1987) mapped the hydrogeologic units of the South Carolina Coastal Plain, including those of Orangeburg County. Miller and Renken (1988) mapped hydrogeologic units of the Southeastern Coastal Plain aquifer systems from Mississippi to North Carolina. Newcome (1989) gave an overview of the ground-water resources in the South Carolina Coastal Plain, including hydrologic characteristics of aquifers in each county. Newcome (1993 and 2005) analyzed and compiled pumping-test data from wells in the Coastal Plain, including 22 tests in Orangeburg County.

NOMENCLATURE AND CLASSIFICATION OF HYDROSTRATIGRAPHIC UNITS

Hydrostratigraphic nomenclature and the classification of hydrostratigraphic units as *provinces, systems, units,* and *zones* is adopted from Aadland and others (1995) and conforms to guidelines established by the U.S. Geological Survey (Laney and Davidson, 1986) and the South Carolina Hydrostratigraphic Subcommittee (Burt, 1987a and b). Top-

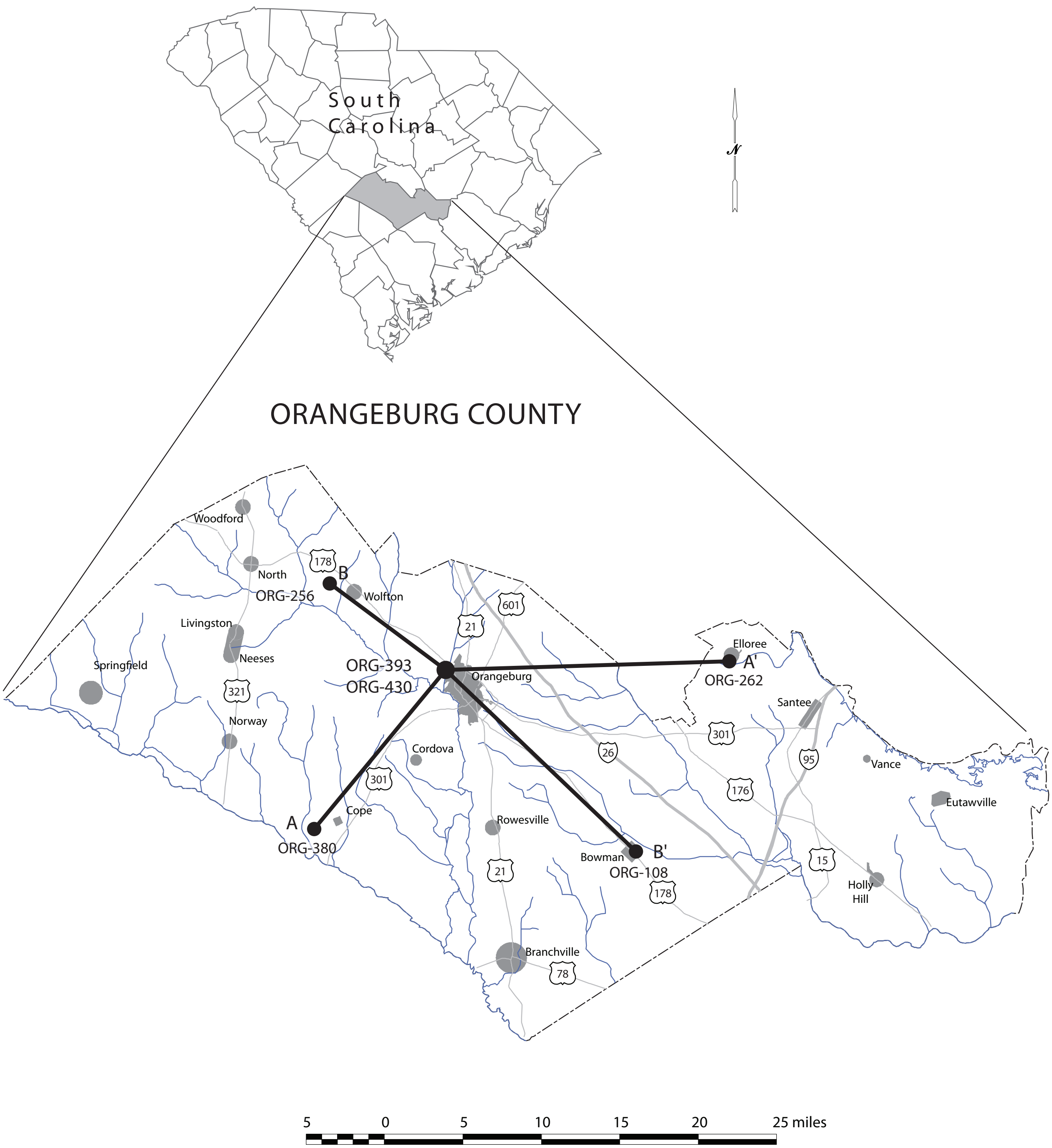

Figure 1. Location of core hole ORG-393 and ORG-430 and hydrogeologic section lines A-A′ and B-B′.

ping the classification hierarchy (level 1) are hydrogeologic provinces, which define major regional rock or sediment packages that behave as a single unified hydrologic unit. The two hydrogeologic provinces in South Carolina are the Southeastern Coastal Plain hydrogeologic province and the Piedmont hydrogeologic province (Aadland and others, 1995). Ranked at level 2 are aquifer and confining systems. Aquifer systems are composed of a single aquifer or two or more aquifers that transmit water on a regional scale. Confining systems are composed of a single confining unit or two or more confining units that impede regional ground water flow. The building blocks of the hierarchical scheme are aquifer units and confining units (level 3). As defined by the subcommittee, an aquifer is a mappable (> 400 mi^2, square miles) body of rock or sediments that is sufficiently permeable to conduct ground water and yield significant quantities of water to wells and springs (Bates and Jackson, 1980). A confining unit is a mappable (> 400 mi^2) body of rock or sediments, of significantly lower hydraulic conductivity than an adjacent aquifer, that is an impediment to ground water flow into or out of an aquifer (Lohman and others, 1972). Aquifer and confining systems and units are formally named for a geographic or cultural feature that is located near a designated type-well locality where the system or unit is representative and well defined. For example, the Crouch Branch aquifer is named after a stream, Crouch Branch, which is near type-well P-27 at the Savannah River Site (SRS). Confining units carry the name of the underlying aquifer that they confine.

Aquifer and confining units can be informally subdivided into zones (level 4) that are characterized by properties significantly different from the rest of the unit, such as hydraulic conductivity, water chemistry, lithology, or color. Names of aquifer and confining zones are informal and describe the unique property that differentiates the zone from the rest of the unit. Zones are locally defined and, as such, their names should be used only at the site where they were defined. No correlation is implied between zones of the same name that were defined at different locations. For example, there is no direct relationship between the “high-permeability zone” of the McQueen Branch aquifer at Orangeburg and the “high-permeability zone” of the McQueen Branch aquifer at Allendale. Furthermore, lateral hydraulic continuity is not implied between zones of the same name that were defined at different sites.

PURPOSES OF REPORT

The purposes of this report are to: 1) delineate the major hydrostratigraphic units at the ORG-393 core hole; 2) relate the units to allostratigraphic and biostratigraphic units and zones; 3) characterize the units in terms of their geological, hydrological, and geophysical properties; 4) correlate the units with those in other test holes and water wells in Orangeburg County; 5) correlate the units with those defined at SRS; and 6) extend to Orangeburg County the hydrostratigraphic nomenclature and hierarchical classification scheme that was introduced at SRS.

METHOD OF STUDY

In previous hydrogeologic framework studies, investigators had to rely mainly on geophysical logs and drill cuttings from water wells and from a few test holes to delineate hydrologic units and to correlate them across the Coastal Plain. Cores were generally unavailable due to their high costs. One of the benefits of a core is that it can be visually examined and samples from known depths can be dated and analyzed. An additional benefit of a core that is drilled to bedrock is that it allows for an entire stratigraphic sequence of the Coastal Plain to be studied and compared and correlated with other cores, drill cuttings, outcrops, and geophysical logs to improve our knowledge of the stratigraphic framework.

In this study, a continuous core from land surface to bedrock was collected in 5- and 10-ft sections. Cores were described (by David C. Prowell of the USGS) in terms of their lithology, grain size, sorting, induration, mineralogy, fossils, structures, and color. Cores were then boxed, photographed, and sampled for particle-size analyses and for paleontological studies. A suite of geophysical logs was obtained from the borehole after the core was drilled. Logs included the 16- and 64-inch short- and long-normal resistivity logs, spontaneous-potential, gamma-ray, and single-point resistance (Plate 1).

Paleontologists with the USGS and Clemson University analyzed the core samples for palynomorphs (pollen and spores from terrestrial plants, and cysts of dinoflagellates) and calcareous nannofossils (remains of golden-brown, single-celled algae that live only in the oceans) in order to determine the age of the sediments. Sixty-five samples had age-diagnostic palynomorphs and 31 samples had age-diagnostic calcareous nannofossils.

Geologists with the USGS identified unconformity-bounded geologic formations (allostratigraphic units). Unconformities are associated with distinct changes in lithology and texture, burrowing, and transgressive lag deposits. Lag deposits in the updip regions of the Coastal Plain usually consist of beds of poorly sorted coarse sand and gravel; downdip, they consist of beds of glauconite, phosphate, pebbles and phosphatized bone, teeth, and shell fragments. Radiation spikes on the gamma-ray log sometimes mark the location of lag beds on geophysical logs, especially in downdip sections consisting of marine deposits. In many cases, however, lag deposits have no distinct log signature and a core is needed to identify their presence.

Biostratigraphic data were examined to determine if fossil assemblages changed above and below each lag deposit, signifying further evidence of an unconformity. In most cases, there were changes; in some deposits, no fossils were available; in others, no significant change in fossils was observed. Final determinations were made on formation boundaries by using the occurrence of lag deposits, geophysical data, and the lithostratigraphic and biostratigraphic data obtained from the core.

Visual inspections of the cores and analyses of geophysical logs and particle-size statistics were used to identify permeable and impermeable layers. Permeable layers were identified from the cores by using detailed descriptions of lithology, texture, and compaction characteristics of the sediments and from an analysis and interpretation of geophysical logs. Statistics from particle-size analyses were used to quantify clay content, grain size, and sorting. Selected samples were sieved at 1-phi intervals through seven sieve trays corresponding to a range in grain size from gravel to mud. Folk and Ward (1957) grain-size parameters, including mean and median grain size and sorting and percentage gravel, sand, and mud were determined for each sample.

Permeable layers were assigned to aquifers and impermeable layers to confining units. Biostratigraphic and allostratigraphic data were used to correlate the aquifers and confining units with those at SRS where a detailed hydrostratigraphic framework has been developed (Aadland and others, 1995). Three monitor wells also were completed at the Orangeburg site to determine if hydraulic gradients exist across the confining units.

ACKNOWLEDGMENTS

Funding for the project was provided through the National Geologic Cooperative Mapping Program. David C. Prowell (USGS) initiated the study and coordinated the drilling activities, described the cores, and determined allostratigraphic and geologic contacts. Jean M. Self-Trail (USGS) described and assigned ages to Cretaceous calcareous nannofossils. Raymond A. Christopher (Clemson University) described and assigned ages to Cretaceous palynomorphs. Laurel M. Bybell (USGS) described and assigned ages to Tertiary calcareous nannofossils. Norman O. Frederiksen (USGS) and Lucy E. Edwards (USGS) described and assigned ages to Tertiary palynomorphs. Karen E. Agerton (SCDNR) assisted in the collection and description of the cores and in the particle-size analyses. Andrew Wachob (SCDNR) obtained the geophysical logs. Eugene Cobbs, II, Eugene Cobbs, III, and Don Queen (all of the USGS) drilled the cores and constructed the monitor wells. The author acknowledges the unique talents of these individuals and extends his gratitude for the expertise that each brought to the project.

HYDROSTRATIGRAPHY

Six hydrostratigraphic systems of the Southeastern Coastal Plain hydrogeologic province are delineated in the ORG-393 core hole—three aquifer systems and three confining systems (Fig. 2 and Plate 1). These systems can be correlated with those mapped at SRS (Aadland and others, 1995). In ascending order, the aquifer systems are the Midville, Dublin, and Floridan. The Midville and Dublin systems consist of a single aquifer each, the McQueen Branch and Crouch Branch, respectively. The Floridan system consists of the Gordon aquifer, the Gordon confining unit, and the Upper Three Runs aquifer. In ascending order, the confining systems are the Appleton, Allendale, and Meyers Branch. Each confining system consists of a single confining unit: the Gramling, McQueen Branch, and Crouch Branch (Fig. 2). Several aquifers and confining units contain zones that have unique hydrogeologic properties. The borehole also penetrated the top of the Piedmont hydrogeologic province.

Piedmont Hydrogeologic Province

The basement complex in South Carolina, designated the Piedmont hydrogeologic province, consists of Paleozoic metamorphic and igneous rocks and consolidated to semiconsolidated Triassic sedimentary rocks (Aadland and others, 1995). Origins of these rocks are different, but their hydraulic properties are similar. The rocks are usually massive, dense, and practically impermeable except where fracture openings are encountered.

The basement complex at the Orangeburg core hole was penetrated from 1,116.5 to 1,138 ft and consists of sedimentary rocks that include mudstone, pebbly mudstone, sandstone, and conglomeritic sandstone of probable Triassic age. The rocks are very poorly sorted and dense from compaction and iron cementation. Primary intergranular porosity is low; however, common slickensided surfaces observed in the core suggest the occurrence of secondary-fracture porosity that could increase flow through the rocks. No drill holes in the vicinity of Orangeburg have been completed as water wells in these rocks, owing to the expected low yields.

Marine (1974) studied similar sedimentary rocks from a Triassic basin at SRS. Field tests indicate hydraulic-conductivity values that range from about 10^{-9} to 10^{-5} ft/d (feet per day). Average total porosity is 8.0 percent for the sandstone and 3.3 percent for the mudstone.

Southeastern Coastal Plain Hydrogeologic Province

The Southeastern Coastal Plain hydrogeologic province in South Carolina encompasses an area of about 22,500 mi^2. About 95 percent of the State's ground-water resources are in the province (Newcome, 1989). It consists of a hydraulically complex sequence of Mesozoic and Cenozoic sedimentary units that are composed of unconsolidated to semiconsolidated layers of sand, clay, limestone, and marl. The province thickens from the Fall Line to the coast where it reaches a maximum thickness of about 4,000 ft at the south end of the State.

The ORG-393 core at Orangeburg penetrated 1,116.5 ft of the Coastal Plain province. Visual examination of the core, particle-size analyses, and geophysical logs, along with hydraulics data such as pumping tests and hydrostatic heads, were used to delineate the principal hydrostratigraphic units in the province (Plate 1).

Appleton Confining System

The Appleton confining system is the lowermost confining system of the Coastal Plain province. In updip areas, it hydraulically separates Coastal Plain sediments from

<table>
<tr><th colspan="4">This report
(Orangeburg County)
(after Aadland and others, 1995)</th><th>South Carolina hydrostratigraphy
Aucott and others (1987)</th><th>Southeastern Region hydrostratigraphy
Miller and Renken (1988)</th><th>South Carolina lithostratigraphy
Colquhoun and others (1983)</th></tr>
<tr><td rowspan="9">SOUTHEASTERN COASTAL PLAIN HYDROGEOLOGIC PROVINCE</td><td></td><td>Surficial aquifer zone</td><td>Unconsolidated, clayey sand.</td><td>Surficial aquifer</td><td>Surficial aquifer</td><td></td></tr>
<tr><td rowspan="3">FLORIDAN AQUIFER SYSTEM</td><td>Upper Three Runs aquifer unit</td><td>Unconsolidated to indurated.
Poorly sorted.
Sandy clay, clayey sand, and limestone.
0-100 ft thick.
Yields probably up to 100 gpm.</td><td>FLORIDAN AQUIFER SYSTEM</td><td>FLORIDAN AQUIFER SYSTEM</td><td>Cooper Group</td></tr>
<tr><td>Gordon confining unit</td><td>Poorly consolidated.
Fine sand in calcareous clay matrix.
Glauconitic and phosphatic at base.
0-150 ft thick.</td><td rowspan="2">Tertiary sand aquifer</td><td rowspan="2">Pearl River aquifer</td><td rowspan="2">Orangeburg Group</td></tr>
<tr><td>Gordon aquifer unit</td><td>Unconsolidated.
Moderately to poorly sorted.
Sand and clayey sand.
50-100 ft thick.
Yields probably up to 500 gpm.</td></tr>
<tr><td>MEYERS BRANCH CONFINING SYSTEM</td><td>Crouch Branch confining unit</td><td>Poorly consolidated.
Carbonaceous, laminated sand and clay.
25-100 ft thick.</td><td>unnamed confining unit</td><td>Chattahoochee River confining unit</td><td>Black Mingo Group</td></tr>
<tr><td>DUBLIN AQUIFER SYSTEM</td><td>Crouch Branch aquifer unit</td><td>Unconsolidated.
Moderately to poorly sorted.
Interbedded sand and clay.
150-250 ft thick.
Yields up to 1,500 gpm.</td><td>Black Creek aquifer</td><td rowspan="3">Chattahoochee River aquifer</td><td>Peedee Formation</td></tr>
<tr><td>ALLENDALE CONFINING SYSTEM</td><td>McQueen Branch confining unit</td><td>Poorly consolidated to well indurated.
Laminated carbonaceous silt and clay.
Sandy, silty marl.
Calcite-cemented beds.
50-200 ft thick.</td><td>unnamed confining unit</td><td>Black Creek Formation</td></tr>
<tr><td>MIDVILLE AQUIFER SYSTEM</td><td>McQueen Branch aquifer unit</td><td>Unconsolidated.
Moderately to poorly sorted.
Sand and clayey sand.
200-300 ft thick.
Yields up to 2,000 gpm.</td><td>Middendorf aquifer</td><td>Middendorf Formation</td></tr>
<tr><td>APPLETON CONFINING SYSTEM</td><td>Gramling confining unit</td><td>Unconsolidated to indurated.
Poorly to very poorly sorted.
Gravel, sand, clayey sand, and clay.
Weakly cemented with silica.
50-300 ft thick.</td><td>unnamed confining unit</td><td>Black Warrior River confining unit</td><td rowspan="2">Crystalline rocks of the Piedmont</td></tr>
<tr><td colspan="3">PIEDMONT HYDROGEOLOGIC PROVINCE</td><td>Sandstone and mudstone.</td><td>Rocks of pre-Cretaceous age</td><td>Base of system</td></tr>
</table>

Figure 2. Generalized description of hydrostratigraphic units delineated in core hole ORG-393 and comparison with hydrostratigraphic units of Aucott and others (1987) and Miller and Renken (1988) and with lithostratigraphic units of Colquhoun and others (1983).

underlying basement rocks; in downdip areas, it overlies and confines a deep Cretaceous aquifer. The system is correlated with the Black Warrior River confining unit of Miller and Renken (1988) (Fig. 2). It was defined for the hydrogeologic properties of sediments penetrated at core hole ALL-348 in Allendale County, S.C., where it is 237 ft thick and consists of saprolite, derived from igneous rock, and interbedded sand, clayey sand, and clay of the Upper Cretaceous Cape Fear Formation (Aadland and others, 1995). Mapping by the author indicates that it underlies the entire Coastal Plain, although it thins considerably in the northwest corner of the Coastal Plain where it consists only of saprolite. Permeable beds occur in the system but are thought to be of limited lateral extent. At the ORG-393 core hole, the system contains one confining unit that is, herein, informally called the "Gramling confining unit," named after Gramling Creek, located just east of Orangeburg.

Gramling confining unit

The Gramling confining unit is the lowermost confining unit in the Orangeburg area. It overlies the Piedmont hydrogeologic province and underlies the McQueen Branch aquifer. At ORG-393, the unit occurs from 977 to 1,116.5 ft and is 140 ft thick. It consists of poorly sorted, clayey quartz sand and gravel beds of Upper Cretaceous age. A lag bed consisting of sand and gravel overlies fractured mudstone and marks the basal contact with the underlying Piedmont hydrogeologic province.

Paleontology and stratigraphic correlation.— Palynomorph assemblages collected from 1,015.7 and 1,105.0 ft indicate an Upper Cretaceous age (Plate 1) and the unit is correlated with the Cape Fear Formation (Turonian through Coniacian, corresponding to calcareous nannofossil zones CC13-14 of Perch-Nielsen, 1979).

The Gramling confining unit at ORG-393 is correlated with the "unnamed" basal confining unit of Aadland and others (1995). It was mapped as "crystalline rocks of the Piedmont" by Colquhoun and others (1983; see the R. Valentine well on section D-D′, p. 23) and is correlated with the lowermost, unnamed confining unit that overlies the Cape Fear aquifer of Aucott and others (1987; see well ORG-49 of section C-C′ on Sheet 5).

Lithology and texture.—The confining unit is characterized by indurated beds of clay and poorly sorted clayey quartz sand and gravel deposited in a series of fining-upward sequences. Weathered and unweathered feldspar, along with minor amounts of monazite and mica and sparse amounts of lignite also occur in the unit.

Three aquifer zones occur in the confining unit, each consisting of loose, gravelly sand in the lower or middle parts of fining-upward sequences. These zones are from 1,032 to 1,050 ft, 1,058 to 1,066 ft, and 1,098 to 1,116.5 ft (Plate 1). Mean grain size of five particle-size analyses from these zones ranges from 1.4 to 0.2 Φ (medium to coarse grained) and averages 0.8 Φ (coarse grained) (Table 1). Gravel averages 10 percent, sand 81 percent, and mud 9 percent. All of the samples are either poorly or very poorly sorted.

Hydrologic properties.—Permeability is generally low and is controlled principally by post-depositional processes. Primary intergranular porosity is low because of poor sorting and detrital clay. Porosity is further reduced by alteration of feldspar to authigenic clay, by weak silicification, and by compaction.

No permeameter tests were made of the Orangeburg core; however, three silty-clay samples from the confining unit at cluster site C-10 (core hole ALL-348) in Allendale County have vertical hydraulic conductivity values that range from 3.8×10^{-3} to 1.6×10^{-2} ft/d and average 1.1×10^{-2} ft/d (Core Laboratories, 1992; Gellici and others, 1995).

At Orangeburg and elsewhere in the State, beds of permeable unconsolidated sand and gravel occur in the confining unit where little or no pore-filling cement or clay is present. The beds are permeable, as indicated by their coarse grain size, lack of clay, and unconsolidated nature, but are thought to have low transmissivities due to their thinness (< 20 ft), their lack of lateral extent, and their lack of connectivity with other permeable layers. Deposited in a fluvial system, they probably occur as hydraulically isolated, channel-fill deposits of limited lateral extent.

Head differentials between permeable beds of the confining unit and those of the overlying McQueen Branch aquifer are unknown inasmuch as no wells are screened in the confining unit in the vicinity of the Orangeburg core hole. Water levels in permeable beds of the confining unit at the C-10 well cluster site in Allendale County are about 9 ft higher than in the McQueen Branch aquifer (Gellici and others, 1995).

Geophysical-log signature.—Low resistivity values on the electric logs are a characteristic feature of the confining unit (Plate 1). Resistivity of the unit averages only 10 ohm-meters. Even those beds consisting of loose sand and little clay have values that rarely exceed 20 ohm-meters. These low values in the sand beds are probably caused by mineralized formation water, possibly the result of long residence times. Deposited as channel-fill sand bars and sand lenses, the beds may be encased in low-permeability sediments and, therefore, poorly connected to recharge areas, resulting in limited flushing. In addition, sediments of the Cape Fear Formation are mineralogically immature, and formation water is in contact with minerals that are prone to dissolution, causing increased mineralization of the water. Low resistivity values are also caused by a high clay content in the confining unit.

Permeable sand beds are identified on the logs as slight deflections to the left on the spontaneous-potential log together with slight increases in resistance on the single-point electric log. Because these sand beds are generally thin, they are easier to identify on the single-point resistance log than on resistivity logs because of the former's greater vertical resolution (Plate 1).

Table 1. Particle-size analyses from core hole ORG-393

Depth (ft)	Weight percent in each size class							Folk and Ward, 1957 (phi)			Gravel (%)	Sand (%)	Mud (%)	Description (Folk and Ward, 1957)	Hydro-stratigraphic unit
	Gravel	Very coarse	Coarse	Med-ium	Fine	Very fine	Mud	Mean	Med-ian	Sort-ing					
10.0	0.0	0.1	0.1	0.7	16.2	41.6	41.2	3.8	3.8	0.8	0.0	58.8	41.2	Lower vf sand; moderately sorted	Surficial aquifer
20.4	0.1	3.4	9.1	6.2	7.9	36.9	36.5	3.3	3.6	1.5	0.1	63.4	36.5	Upper vf sand; poorly sorted	do.
30.0	0.1	6.8	11.3	2.4	1.5	28.9	49.1	3.2	4.0	1.7	0.1	50.8	49.1	Upper vf sand; poorly sorted	U. Three Runs aq.
40.5	0.0	0.1	0.1	0.1	0.1	9.1	90.3	4.4	4.4	0.4	0.0	9.6	90.3	Coarse silt; well sorted	do.
50.0	0.1	2.2	10.4	7.1	8.7	38.1	33.4	3.2	3.6	1.5	0.1	66.5	33.4	Upper vf sand; poorly sorted	do.
60.2	0.0	0.1	0.1	2.0	17.0	53.9	26.9	3.6	3.6	0.8	0.0	73.1	26.9	Lower vf sand; moderately sorted	do.
80.0	0.0	0.2	0.2	0.3	1.4	18.1	79.9	4.3	4.4	0.5	0.0	20.1	79.9	Coarse silt; well sorted	do.
92.0	0.0	0.1	0.3	0.8	2.9	30.0	66.0	4.1	4.2	0.6	0.0	34.0	66.0	Coarse silt; well sorted	Gordon conf. unit
120.0	10.4	5.6	3.9	4.0	8.0	29.8	38.4	2.7	3.6	2.1	10.4	51.3	38.4	Lower f sand; very poorly sorted	do.
140.1	0.1	1.6	4.0	4.5	10.2	20.2	59.5	3.8	4.2	1.2	0.1	40.4	59.5	Lower vf sand; poorly sorted	do.
170.0	0.1	4.0	9.4	17.7	18.1	7.8	42.8	3.0	3.1	1.6	0.1	57.0	42.8	Lower f sand; poorly sorted	do.
214.0	0.1	10.0	54.3	20.3	4.8	5.1	5.4	0.9	0.7	1.2	0.1	94.5	5.4	Lower c sand; poorly sorted	Gordon aquifer
224.0	1.5	6.5	65.8	10.3	4.2	4.9	6.7	0.9	0.6	1.2	1.5	91.8	6.7	Lower c sand; poorly sorted	do.
240.0	1.5	22.6	47.6	15.5	4.4	2.3	6.0	0.7	0.5	1.3	1.5	92.5	6.0	Lower c sand; poorly sorted	do.
251.0	4.2	19.2	28.7	17.1	10.2	9.8	10.9	1.3	0.9	1.8	4.2	84.9	10.9	Upper m sand; poorly sorted	do.
270.0	2.8	19.0	51.6	12.0	4.5	3.2	7.0	0.7	0.5	1.3	2.8	90.2	7.0	Lower c sand; poorly sorted	do.
300.0	0.6	7.4	21.0	30.0	7.6	1.8	31.6	2.2	1.7	1.8	0.6	67.8	31.6	Upper f sand; poorly sorted	Crouch Branch aq.
310.0	2.9	16.8	28.9	25.4	7.3	4.2	14.5	1.5	1.1	1.8	2.9	82.6	14.5	Upper m sand; poorly sorted	do.
320.0	8.6	39.9	27.0	8.0	5.9	2.9	7.8	0.4	0.1	1.6	8.6	83.7	7.8	Upper c sand; poorly sorted	do.
336.0	0.1	2.8	8.8	10.4	4.5	3.3	70.2	3.5	4.3	1.5	0.1	29.7	70.2	Upper vf sand; poorly sorted	do.
350.0	0.0	1.3	20.4	45.5	18.3	3.3	11.2	1.8	1.6	1.2	0.0	88.8	11.2	Lower m sand; poorly sorted	do.
360.0	0.1	5.4	39.6	33.0	10.6	2.5	8.9	1.3	1.2	1.3	0.1	91.0	8.9	Upper m sand; poorly sorted	do.
370.0	0.8	23.4	49.8	8.4	6.1	2.4	9.1	0.8	0.5	1.4	0.8	90.1	9.1	Lower c sand; poorly sorted	do.
380.0	0.6	11.3	32.7	29.9	13.7	2.6	9.2	1.3	1.2	1.4	0.6	90.2	9.2	Upper m sand; poorly sorted	do.
390.0	0.1	3.7	42.4	34.0	8.2	2.5	9.1	1.3	1.1	1.2	0.1	90.8	9.1	Upper m sand; poorly sorted	do.
400.0	0.1	6.2	27.9	28.2	23.4	3.3	11.0	1.6	1.6	1.4	0.1	88.9	11.0	Lower m sand; poorly sorted	do.
410.0	2.9	25.3	41.4	15.1	4.4	2.0	8.8	0.7	0.5	1.4	2.9	88.3	8.8	Lower c sand; poorly sorted	do.
420.0	12.3	36.1	29.3	11.0	4.0	1.5	5.8	0.2	0.1	1.5	12.3	81.9	5.8	Upper c sand; poorly sorted	do.
430.0	5.2	17.3	27.5	16.2	14.7	7.7	11.5	1.3	1.0	1.8	5.2	83.3	11.5	Upper m sand; poorly sorted	do.
440.0	0.0	0.6	13.7	37.9	24.7	10.3	12.9	2.2	1.9	1.3	0.0	87.1	12.9	Upper f sand; poorly sorted	do.
450.0	0.0	0.1	0.3	7.9	63.0	15.2	13.5	2.9	2.7	0.9	0.0	86.5	13.5	Lower f sand; moderately sorted	do.
460.0	0.2	3.8	29.4	25.0	27.6	6.8	7.3	1.7	1.7	1.3	0.2	92.6	7.3	Lower m sand; poorly sorted	do.
470.0	0.0	0.0	0.1	2.9	8.8	57.0	31.3	3.7	3.7	0.7	0.0	68.7	31.3	Lower vf sand; moderately sorted	do.
480.0	0.1	13.6	38.9	13.8	17.4	7.7	8.4	1.3	0.9	1.5	0.1	91.5	8.4	Upper m sand; poorly sorted	do.
490.0	0.0	0.1	0.3	4.3	28.4	51.3	15.7	3.2	3.3	0.8	0.0	84.3	15.7	Upper vf sand; moderately sorted	do.
500.0	0.0	0.1	3.5	38.5	40.0	6.5	11.3	2.7	2.2	1.0	0.0	88.7	11.3	Upper f sand; poorly sorted	do.
510.0	0.0	0.1	0.9	16.3	45.4	16.7	20.6	3.0	2.7	1.1	0.0	79.4	20.6	Lower f sand; poorly sorted	do.

vf, very fine; f, fine; m, medium; c, coarse

Gravel: < -1 phi; very coarse sand: -1 to 0 phi; coarse sand: 0 to 1 phi; medium sand: 1 to 2 phi; fine sand: 2 to 3 phi; very fine sand: 3 to 4 phi; mud: > 4 phi

Table 1 (continued). Particle-size analyses from core hole ORG-393

Depth (ft)	Weight percent in each size class: Gravel	Very coarse	Coarse	Med-ium	Fine	Very fine	Mud	Folk and Ward, 1957 (phi): Mean	Med-ian	Sort-ing	Gravel (%)	Sand (%)	Mud (%)	Description (Folk and Ward, 1957)	Hydro-stratigraphic unit
695.0	1.4	14.8	28.9	21.2	6.1	3.0	24.6	1.9	1.2	1.9	1.4	74.1	24.6	Lower m sand; poorly sorted	McQueen Branch aq.
705.0	2.6	16.0	39.9	22.9	10.0	2.4	6.2	1.0	0.8	1.4	2.6	91.2	6.2	Lower c sand; poorly sorted	do.
722.6	0.0	0.1	1.9	9.8	27.8	24.3	36.1	3.4	3.4	1.1	0.0	63.9	36.1	Upper vf sand; poorly sorted	do.
742.0	0.0	0.1	2.7	66.1	22.3	2.3	6.5	1.9	1.7	0.9	0.0	93.5	6.5	Lower m sand; moderately sorted	do.
752.0	2.0	9.2	25.6	27.3	14.8	3.4	17.8	1.9	1.5	1.8	2.0	80.3	17.8	Lower m sand; poorly sorted	do.
780.0	2.1	12.3	30.8	39.7	4.9	2.1	8.0	1.1	1.1	1.3	2.1	90.0	8.0	Upper m sand; poorly sorted	do.
790.0	0.1	4.0	26.1	51.0	11.2	1.3	6.4	1.4	1.4	1.1	0.1	93.5	6.4	Upper m sand; poorly sorted	do.
800.0	1.5	13.0	44.6	23.9	7.6	2.1	7.2	1.0	0.8	1.3	1.5	91.3	7.2	Lower c sand; poorly sorted	do.
810.0	1.1	7.2	21.6	30.8	15.6	8.7	15.0	2.0	1.7	1.7	1.1	84.0	15.0	Lower m sand; poorly sorted	do.
820.0	9.9	35.2	35.5	12.6	2.1	1.2	3.6	0.2	0.1	1.2	9.9	86.5	3.6	Upper c sand; poorly sorted	do.
830.0	5.7	27.0	38.0	12.2	6.1	2.5	8.5	0.7	0.5	1.5	5.7	85.8	8.5	Lower c sand; poorly sorted	do.
840.0	0.1	4.5	32.3	42.8	5.9	2.9	11.5	1.5	1.3	1.3	0.1	88.2	11.5	Upper m sand; poorly sorted	do.
850.0	1.4	13.3	36.8	20.0	15.7	4.0	8.9	1.3	1.0	1.5	1.4	89.7	8.9	Upper m sand; poorly sorted	do.
860.0	2.2	7.7	37.3	37.5	7.9	2.3	5.1	1.1	1.1	1.2	2.2	92.6	5.1	Upper m sand; poorly sorted	do.
870.0	7.2	41.1	27.6	7.6	6.8	3.6	6.1	0.5	0.1	1.5	7.2	86.7	6.1	Upper c sand; poorly sorted	do.
880.0	0.2	8.4	42.1	35.5	5.3	2.0	6.4	1.0	1.0	1.1	0.2	93.4	6.4	Upper m sand; poorly sorted	do.
890.0	0.0	0.1	2.0	33.7	44.6	5.7	14.0	2.5	2.3	1.1	0.0	86.0	14.0	Upper f sand; poorly sorted	do.
900.0	0.2	3.6	14.4	25.1	22.2	3.1	31.5	2.5	2.3	1.6	0.2	68.4	31.5	Lower f sand; poorly sorted	do.
910.0	1.9	11.8	29.7	29.1	13.0	3.1	11.4	1.4	1.2	1.5	1.9	86.6	11.4	Upper m sand; poorly sorted	do.
920.0	0.1	3.8	56.1	30.1	3.9	0.9	5.2	0.9	0.8	1.0	0.1	94.8	5.2	Lower c sand; poorly sorted	do.
930.0	0.4	8.8	35.2	26.7	7.4	2.4	19.0	1.9	1.2	1.8	0.4	80.5	19.0	Lower m sand; poorly sorted	do.
940.0	0.0	0.1	0.6	30.6	42.2	3.7	22.7	2.7	2.4	1.3	0.0	77.3	22.7	Lower f sand; poorly sorted	do.
975.0	4.7	20.7	36.9	17.1	7.1	3.1	10.4	1.0	0.7	1.6	4.7	84.9	10.4	Lower c sand; poorly sorted	do.
1,036.0	14.6	31.8	30.0	13.7	4.7	1.8	3.3	0.2	0.1	1.3	14.6	82.1	3.3	Upper c sand; poorly sorted	Gramling conf. unit
1,046.0	5.2	26.0	39.8	16.3	5.0	2.2	5.4	0.6	0.5	1.4	5.2	89.4	5.4	Lower c sand; poorly sorted	do.
1,063.0	13.0	19.3	27.5	22.7	7.4	2.5	7.5	0.7	0.6	1.7	13.0	79.5	7.5	Lower c sand; poorly sorted	do.
1,100.0	11.3	20.1	25.5	12.1	6.0	4.1	20.9	1.4	0.7	2.2	11.3	67.9	20.9	Upper m sand; very poorly sorted	do.
1,110.0	4.4	17.6	37.7	23.0	7.0	2.0	8.3	0.9	0.7	1.4	4.4	87.4	8.3	Lower c sand; poorly sorted	do.

vf, very fine; f, fine; m, medium; c, coarse
Gravel: < -1 phi; very coarse sand: -1 to 0 phi; coarse sand: 0 to 1 phi; medium sand: 1 to 2 phi; fine sand: 2 to 3 phi; very fine sand: 3 to 4 phi; mud: > 4 phi

Midville Aquifer System

The Midville aquifer system overlies the Appleton confining system and was defined by Clarke and others (1985) for hydrogeologic properties of sediments penetrated in well 28X1, near the town of Midville, Ga. The system is correlated with the lower part of the Chattahoochee River aquifer of Miller and Renken (1988) (Fig. 2). In South Carolina, sediments penetrated by reference-well P-24 at SRS are typical of the aquifer system (Aadland and others, 1995). At this well, the Midville is 271 ft thick and consists of unconsolidated, medium to very coarse sand of the Middendorf Formation (Upper Cretaceous) and fine-grained, clayey sand of the lower part of the Black Creek Formation (Campanian). Although the system contains several aquifers in other parts of the State, only the McQueen Branch aquifer is present at ORG-393.

McQueen Branch aquifer unit

The McQueen Branch aquifer is the lowermost aquifer in the Orangeburg area. It overlies the Gramling confining unit and is confined by the McQueen Branch confining unit. In the ORG-393 core hole, the aquifer occurs from 693 to 977 ft and is 284 ft thick. It consists of quartz sand beds and interbedded sand and clay of Upper Cretaceous age. Poorly consolidated, coarse-grained sand and gravel overlying dense, weakly cemented sand and gravel marks the contact between the aquifer and the underlying Gramling confining unit.

Paleontology and stratigraphic correlation.— Palynomorph assemblages collected from 712.6, 740.7, 741.1, 744.0, 808.4, 859.0, and 892.1 ft all indicate a lower Campanian age (calcareous nannofossil zone CC-19; Plate 1). One calcareous nannofossil assemblage from 724.5 ft also indicates a lower Campanian age. The aquifer includes strata of three formations that are hydraulically connected. In ascending order, these include: 1) the upper part of the Cape Fear Formation; 2) the Cane Acre Formation; and 3) the lower part of the Coachman Formation (Plate 1).

Most of the aquifer, from 711 to 895 ft, consists of the Cane Acre Formation (lower Campanian, corresponding to calcareous nannofossil zone CC-19). In previous reports (Colquhoun and others, 1983; Aucott and others, 1987; Aadland and others, 1995), the basal Cretaceous formation in updip regions of the Coastal Plain was mapped as the Middendorf Formation (Santonian). Hazel and others (1977) originally assigned an early late Austinian age to the Middendorf, indicating a Santonian or lower Campanian age. Gohn (1992), citing several supporting paleontological studies (Christopher, 1982; Sohl and Owens, 1991; Valentine, 1984), placed the Middendorf Formation within the Santonian Stage at the USGS-Clubhouse Crossroads #1 core. Recent studies of cores and outcrops (Prowell and others, 2003) and paleontological data collected from the ORG-393 core indicate that strata previously mapped as the Middendorf Formation is lower Campanian (calcareous nannofossil zone CC-19) and should, therefore, be included in the Black Creek Group (Campanian). To the author's knowledge, no Santonian dates (corresponding to calcareous nannofossil zones CC16-17) have been collected from updip cores or outcrops. Prowell and others (2003) reexamined the type section of the Middendorf Formation in Chesterfield County, S.C., and concluded that it was upper Campanian or Maastrichtian in age, not Santonian.

Gohn (1992) defined the Cane Acre Formation in the USGS-Clubhouse Crossroads #1 core (DOR-37) and assigned a lower Campanian age to the formation (calcareous nannofossil zone CC-19). It is the lowermost formation of the Black Creek Group (see Gohn, 1992, and Gohn and Campbell, 1992, for a lithologic and biostratigraphic description of the Cane Acre Formation). Accordingly, the name Cane Acre is used in this report for strata dated as lower Campanian. The term Middendorf Formation is not applied in this report.

The lower part of the McQueen Branch aquifer consists of the Cape Fear Formation (Turonian through Coniacian, corresponding to calcareous nannofossil zones CC13-14) and the upper 17 ft consists of the lower part of the Coachman Formation (middle Campanian, corresponding to calcareous nannofossil zone CC-20). The Coachman is also part of the Black Creek Group (see Gohn, 1992, and Self-Trail and Gohn, 1996, for a lithologic and biostratigraphic description of the Coachman Formation) (Plate 1).

The McQueen Branch aquifer at ORG-393 is correlated with the McQueen Branch aquifer mapped in west-central South Carolina by Aadland and others (1995). It is also correlated with the Lower Middendorf aquifer and the Middendorf Formation of Colquhoun and others (1983; see the R. Valentine well on section D-D′, p. 23) and with the Middendorf aquifer of Aucott and others (1987; see well ORG-49 of section C-C′ on Sheet 5).

Lithology and texture.—The aquifer is characterized by unconsolidated, moderately to poorly sorted, medium to coarse quartz sand in a kaolin matrix. Clay beds as thick as 17 ft are present. On the whole, the aquifer consists of 238 ft of sand and clayey sand in seven beds and 46 ft of sandy clay and clay in six beds. Mean grain size of 23 particle-size analyses ranges from 3.4 to 0.2 Φ (very fine to coarse grained) and averages 1.5 Φ (medium grained) (Table 1). Most samples are medium or coarse grained and poorly sorted. Gravel averages 2 percent, sand 85 percent, and mud 13 percent.

Hydrologic properties.—The aquifer is subdivided into several zones on the basis of relative permeability (Plate 1). The lower part of the aquifer (922 to 977 ft), which correlates with the Cape Fear Formation, is perhaps the least permeable. It consists mainly of fining-upward sequences of poorly consolidated to well-indurated clayey sand and gravel with minor, partly decomposed feldspar. Gravel content can be as high as 15 percent. Although grain size is relatively coarse in this zone, permeability is reduced by interstitial clay and silica cement. Three particle-size analyses from the zone indicate a mean grain size of 1.9 Φ (medium grained) and an average mud content of 17 percent (Table 1). Gravel ranges from 0 to 5 percent.

The middle zone (774 to 922 ft), which consists of the lower half of the Cane Acre Formation and the uppermost part of the Cape Fear Formation, is the most permeable and consists of unconsolidated, poorly sorted, fine to very coarse quartz sand with minor amounts of gravel. Carbonaceous clay beds, 1 to 8 ft thick, occur in the zone. Fifteen particle-size analyses indicate a mean grain size of 1.3 Φ (medium grained) and an average mud content of 10 percent (Table 1). Permeability is excellent in this zone, owing to its coarse-grained texture and low clay content.

The upper part of the aquifer (693 to 774 ft) consists of the upper part of the Cane Acre Formation and the lower part of the Coachman Formation (Plate 1). Permeability occurs in three discrete beds that consist of unconsolidated, fine to very coarse, clayey quartz sand. Intervening clay beds range from 5 to 17 ft in thickness and consist of relatively impermeable sandy clay and dense clay with slickensided surfaces. Five particle-size analyses of the sand beds indicate a mean grain size of 2.0 Φ (fine grained) and an average mud content of 18 percent (Table 1).

In Orangeburg County, the McQueen Branch aquifer is used mainly by large industries, although several small towns and a coal-fired power plant at Cope, S.C., also utilize the aquifer. A 7-day pumping test made at Cope, about 13 miles southwest of the core hole, indicates a transmissivity of 27,000 ft^2/d (feet squared per day) (Newcome, 2000), which is comparable to that observed in west-central South Carolina, where it averages about 28,000 ft^2/d (Aadland and others, 1995). The transmissive thickness of the aquifer at Cope is 194 ft and the calculated hydraulic conductivity is 139 ft/d. A storage coefficient of 2.7 x 10^{-4} was calculated from the test.

About 9 miles south of the core hole, at the Greenwood Mills plant and at Hughes Aircraft Company, pumping tests indicate transmissivities of 17,000 and 20,000 ft^2/d and hydraulic conductivities of 93 and 110 ft/d, respectively. At the town of Bowman, about 16 miles southeast of the core hole, a pumping test indicates a transmissivity of 19,000 ft^2/d and a hydraulic conductivity of 110 ft/d. The average transmissivity of these four Orangeburg County tests is 21,000 ft^2/d, and the average hydraulic conductivity is 113 ft/d. Slightly lower hydraulic-conductivity values to the south and east reflect a trend of decreasing grain size, which is evident in core holes farther to the south and east in Dorchester and Berkeley Counties.

No monitor wells are completed in the McQueen Branch aquifer at the core site; however, the water-level elevation at Greenwood Mills in a deep production well (ORG-79) is +162 ft, or 18 ft below land surface (measured in November 2001; Hockensmith, 2003).

Geophysical-log signature.—The middle zone, which is the most permeable part of the aquifer, is characterized by high resistivity on the long-normal log and by low radiation on the gamma-ray log (Plate 1). Resistivity averages 270 ohm-meters. Low radiation is attributed to the low clay content of the aquifer and is a notable feature on geophysical logs at other core holes in the west-central region of the Coastal Plain.

Resistivity averages only 71 ohm-meters through the lower zone of the aquifer, steadily decreasing downhole (Plate 1), and 70 ohm-meters through the upper zone. These lower values reflect the higher clay content of these zones.

Allendale Confining System

The Allendale confining system hydraulically separates the Midville and Dublin aquifer systems. Miller and Renken (1988) combined the Middendorf and Black Creek aquifers (their Chattahoochee River aquifer), and so the Allendale confining system has no correlative unit in their framework (see Fig. 2). The system was defined for hydrogeologic properties of sediments penetrated at core hole ALL-347 in Allendale County, S.C. (Aadland and others, 1995), where it is 162 ft thick and consists mainly of clay, silty clay, and micritic silt and clay of the Black Creek Formation (Campanian). At the ORG-393 core hole the system consists of the McQueen Branch confining unit.

McQueen Branch confining unit

The McQueen Branch confining unit overlies and confines the McQueen Branch aquifer and underlies the Crouch Branch aquifer. At ORG-393, the unit occurs from 514 to 693 ft and is 179 ft thick. It consists of carbonaceous clay and calcareous clay beds of Upper Cretaceous age. The lower boundary is marked by beds of carbonaceous thinly laminated clay and fine sand that overlie unconsolidated fine to very coarse sand of the McQueen Branch aquifer.

Paleontology and stratigraphic correlation.— Palynomorph assemblages collected from 679.0 and 683.1 ft indicate a middle Campanian age (calcareous nannofossil zone CC-20; Plate 1). Palynomorph assemblages collected from 612.1, 630.0, 649.8 and 662.0 ft and calcareous nannofossils collected from 612.5, 618.4, 624.3, 629.8, 640.0, 649.7, 662.2, and 667.1 ft all indicate a late middle Campanian age (calcareous nannofossil zone CC-21; Plate 1). A palynomorph assemblage collected from 594.9 ft and calcareous nannofossils collected from 561.9, 567.1, 572.1, 578.5, 584.9, and 589.6 ft all indicate an upper Campanian age (calcareous nannofossil subzone CC-22c; Plate 1). A calcareous nannofossil assemblage from 600.8 ft was collected from a lag deposit and has a late middle Campanian age. Palynomorph assemblages collected from 522.0 and 545.8 ft and a calcareous nannofossil assemblage from 556.8 ft indicate an upper Campanian age (calcareous nannofossil zone CC-23 (?); Plate 1).

The confining unit consists of all or parts of four formations. In ascending order these include: 1) the upper part of the Coachman Formation; 2) the Bladen Formation; 3) the middle Donoho Creek unit; and 4) the lower part of the upper Donoho Creek unit (Plate 1).

The lower part of the confining unit, from 670 to 693 ft, correlates with the upper part of the Coachman Formation (middle Campanian, corresponding to calcareous nannofossil zone CC-20). From 606 to 670 ft, the confining unit consists of the Bladen Formation, which is also part of the Black Creek Group (late middle Campanian, corresponding to calcareous nannofossil zone CC-21) (see Gohn, 1992, and Self-Trail and Gohn, 1996, for a lithologic and biostratigraphic description of the Bladen Formation). From 557 to 606 ft the confining unit consists of the middle Donoho Creek unit (upper Campanian, corresponding to calcareous nannofossil subzone CC-22c). The upper part of the confining unit, from 514 to 557 ft, consists of the upper Donoho Creek unit (upper Campanian, corresponding to calcareous nannofossil zone CC-23).

The Donoho Creek Formation is the uppermost formation of the Black Creek Group (Sohl and Owens, 1991; Gohn, 1992). A biostratigraphic subdivision of the formation has been proposed (D.C. Prowell, oral commun., 2002; see also Self-Trail and Gohn, 1996) but has not been formalized. For the purposes of this report the Donoho Creek Formation is divided into three informal units called the lower, middle, and upper Donoho Creek units, corresponding to calcareous nannofossil subzones CC-22a/b and CC-22c, and zone CC-23, respectively.

The McQueen Branch confining unit at ORG-393 is correlated with the McQueen Branch confining unit mapped in west-central South Carolina by Aadland and others (1995). It is also correlated with the "confining beds" between the Middendorf and Black Creek aquifer systems of Colquhoun and others (1983; see the R. Valentine well on section D-D', p. 23), with the lower part of the Black Creek Formation of Colquhoun and others (1983) (Fig. 2), and with the unnamed confining unit between the Middendorf and Black Creek aquifers of Aucott and others (1987; see well ORG-49 of section C-C′ on Sheet 5).

Lithology and texture.—Lithologically, the confining unit is heterogeneous, comprising parts of four formations (Plate1). The lower part (670 to 693 ft), which correlates with the Coachman Formation, consists of thinly laminated carbonaceous clay and very fine to fine, well-sorted, quartz sand with minor lignite (Plate 1). From 606 to 670 ft, the unit correlates with the Bladen Formation, which consists of calcareous clay that contains about 10 percent very fine to fine, well-sorted, quartz sand and shell fragments. Fifteen calcite-cemented bivalve-rich beds occur in the interval, ranging in thickness from 0.4 to 1.4 ft. These beds are lithified and have a low porosity and permeability, reducing leakage through the confining unit. The beds total 13 ft, constituting about 20 percent of the interval.

In the interval from 557 to 606 ft, the confining unit is correlated with the middle Donoho Creek unit and consists of sandy, silty marl with common bivalve shells and shell fragments. A permeable lag bed occurs at the base of the interval (599 to 606 ft) that consists of fine to coarse, clayey, calcareous sand.

The upper part of the unit, from 514 to 557 ft, correlates with the upper Donoho Creek unit and consists of laminated silty clay and clayey sand. The sand component is well sorted and consists of very fine to fine quartz sand. A lag bed (553 to 557 ft) of coarse-grained calcareous sand, phosphate, bivalve fragments, and clay clasts marks the base of the interval.

Hydrologic properties.—No permeameter tests were made of the core; however, tests of nine clay and sandy clay samples from the confining unit at SRS indicate vertical hydraulic-conductivity values that range from 6.80×10^{-5} to 2.09×10^{-2} ft/d and average 3.77×10^{-4} ft/d (Bledsoe and others, 1990).

Most of the formations composing the confining unit were deposited in open-marine environments and, therefore, their lithologies are probably homogeneous over wide areas. Mapping by the author indicates that the confining unit is thick and continuous from Orangeburg County to Allendale County and into eastern Georgia. A 7-day pumping test at Cope, S.C., showed no water-level declines in the overlying Crouch Branch aquifer while the McQueen Branch aquifer was being pumped at 2,200 gpm (gallons per minute), indicating good confinement.

Geophysical-log signature.—Low resistivity and high radiation values are recorded throughout the confining unit owing to its high clay content (Plate 1). Long-normal resistivity averages 5 ohm-meters.

A spike on the gamma-ray log at about 557 ft marks a lag bed at the base of the upper Donoho Creek unit (Plate 1). This bed consists of coarse-grained calcareous sand with common 6-mm phosphate grains, 30-mm clay clasts, bivalve fragments, sparse shark teeth, and rare pieces of bone. Another lag bed at the base of the middle Donoho Creek unit (606 ft) shows no discernible spike in radiation. This bed also consists of coarse-grained calcareous sand with common 7-mm phosphate grains, 20-mm cemented sand clasts, bivalve fragments, and sparse shark teeth.

Calcite-cemented zones in the Bladen Formation are identified on the single-point resistance log as sharp deflections to the right (Plate 1), indicating dense rocks of low porosity.

Dublin Aquifer System

The Dublin aquifer system overlies the Allendale confining system and was defined by Clarke and others (1985) for the hydrogeologic properties of sediments penetrated in well 21U4, near the town of Dublin, Ga. The system is correlated with the upper part of the Chattahoochee River aquifer of Miller and Renken (1988) (Fig. 2). In South Carolina, sediments representative of the Dublin aquifer system were penetrated in reference well P-22 at SRS (Aadland and others, 1995). There, the system is 213 ft thick and consists of well-sorted sand and lignitic, micaceous, clayey sand of the Black Creek Formation (Campanian) and moderately sorted medium to coarse sand and interbedded sand and clay of the Steel Creek Formation (Maastrichtian; age equivalent of the Peedee Formation, see discussion below). In other parts of the State the aquifer system can contain several aquifers; however, at the ORG-393 core hole the system consists of a single unit, the Crouch Branch aquifer.

Crouch Branch aquifer unit

The Crouch Branch aquifer overlies the McQueen Branch confining unit and is confined by the overlying Crouch Branch confining unit. At ORG-393, the aquifer occurs from 298 to 514 ft and is 216 ft thick. It consists of clayey quartz sand beds of Upper Cretaceous age. The lower boundary is gradational, consisting of laminated sand and clay overlying interbedded clay and sand of the McQueen Branch confining unit.

Paleontology and stratigraphic correlation.— Palynomorph assemblages collected from 468.5, 489.3, 500.0, 511.3, and 513.6 ft all indicate an upper Campanian age (calcareous nannofossil zone CC-23(?)). One palynomorph assemblage from 446.0 ft indicates an upper Maastrichtian age (calcareous nannofossil subzone CC-25a). Palynomorph assemblages collected from 405.0, 412.0, and 417.9 ft indicate an upper Maastrichtian age (calcareous nannofossil subzone CC-25b). Palynomorph assemblages collected from 372.3 and 384.0 ft indicate an upper Maastrichtian age (calcareous nannofossil subzone CC26a(?)). One palynomorph assemblage from 320.7 ft indicates an upper Maastrichtian age (calcareous nannofossil subzone CC-26b(?)). The aquifer contains all or parts of five formations and, in ascending order, include: 1) the upper part of the upper Donoho Creek unit; 2) the lower Peedee unit; 3) the middle Steel Creek unit; 4) the upper Steel Creek unit; and 5) the Sawdust Landing Formation (Plate 1).

The lower part of the aquifer, from 468 to 514 ft, consists of the upper Donoho Creek unit (upper Campanian, corresponding to calcareous nannofossil zone CC-23(?)). The middle of the aquifer consists of the lower Peedee unit from 446 to 468 ft (lower Maastrichtian, corresponding to calcareous nannofossil subzone CC-25a), the middle Steel Creek unit from 398 to 446 ft (lower to upper Maastrichtian, corresponding to calcareous nannofossil subzone CC-25b), and the upper Steel Creek unit from 323 to 398 ft (upper Maastrichtian, corresponding to calcareous nannofossil subzone CC-26a(?)). The top of the aquifer, from 298 to 323 ft, consists of the Sawdust Landing Formation (upper Maastrichtian, corresponding to calcareous nannofossil subzone CC-26b(?)) (Plate 1).

A fluvial, coarse-grained unit of the Maastrichtian Peedee Formation was named the Steel Creek Formation (Fallaw and Price, 1995) in the west-central region of the South Carolina Coastal Plain because of substantial differences between the lithology of the Peedee Formation at its type locality (Heron, 1958) in eastern Florence County and that observed at the Savannah River Site. At its type locality, the Peedee Formation consists of dark silt and glauconitic quartz sand with marine fossils (Fallaw and Price, 1995). The formation inhibits flow and hydraulically behaves like a confining unit. At SRS, the Peedee consists of light-colored fine to coarse-grained quartz sand and oxidized kaolinitic clay (Fallaw and Price, 1995) and constitutes a good aquifer.

Christopher and Prowell (2002) recognized unconformities in the Peedee section in cores drilled throughout the Coastal Plain and proposed a subdivision of the Peedee Formation into three unconformity-bounded palynological zones. These were informally called the lower, middle, and upper Peedee units where Peedee-type lithologies were observed and the lower, middle, and upper Steel Creek units where Steel Creek-type lithologies were observed.

Disconformably overlying the Peedee and Steel Creek Formations is the Sawdust Landing Formation. Until recently, fossils were unavailable from the formation, and most geologists considered it to be of lower Paleocene age (Colquhoun and Muthig, 1991; Nystrom and others, 1991; Fallaw and Price, 1995; Aadland and others, 1995). Frederiksen and others (2000), however, recovered an Upper Cretaceous palynomorph from the Sawdust Landing Formation at a depth of 320.7 ft in the ORG-393 core. The pollen assemblage in this sample contains the palynomorph *Rugubivesiculities*, which places it in the Upper Cretaceous (Frederiksen and others, 2000). As such, the formation is now considered Maastrichtian in age (Christopher and Prowell, 2002).

The Crouch Branch aquifer at ORG-393 is correlated with the Crouch Branch aquifer mapped in west-central South Carolina by Aadland and others (1995). The aquifer is also correlated with the Black Creek aquifer system of Colquhoun and others (1983; see the R. Valentine well on section D-D′, p. 23), with the Black Creek and Peedee Formations of Colquhoun and others (1983) (Fig. 2), and with the Black Creek aquifer of Aucott and others (1987; see well ORG-49 of section C-C′ on Sheet 5).

Lithology and texture.—The aquifer is characterized by unconsolidated, moderately to poorly sorted, very fine to coarse quartz sand with a kaolin matrix and by interbedded sand and carbonaceous clay. Clay beds as thick as 7 ft are present. Mean grain size of 21 particle-size analyses ranges from 3.7 to 0.2 Φ (very fine to coarse grained) and averages 1.8 Φ (medium grained) (Table 1). Most samples are either fine or medium grained and most are poorly sorted. Gravel averages 2 percent, sand 83 percent, and mud 15 percent.

The lower part of the aquifer, from 468 to 514 ft, correlates with the upper Donoho Creek unit and consists mainly of quartz sand laminated with carbonaceous clay. Clay beds are as thick as 0.5 ft, but most are less than several inches. Sand beds may be several feet thick, but most are laminated in varying degree with carbonaceous clay. Mean grain size of five particle-size analyses from the lower zone ranges from 3.7 to 1.3 Φ (very fine to medium grained) (Table 1) and averages 2.8 Φ (fine grained). Most of the samples are very fine or fine grained and most are poorly sorted. Sand averages 83 percent and mud 17 percent.

The middle part of the aquifer, from 348 to 468 ft, correlates with the lower Peedee unit, the middle Steel Creek unit, and most of the upper Steel Creek unit. This part of the aquifer consists largely of unconsolidated, slightly clayey, fine to very coarse grained quartz sand. Few clay beds are present and, where present, are generally less than 0.5 ft thick. Mean grain size in 12 particle-size analyses from the upper zone ranges from 2.9 to 0.2 Φ (fine to coarse grained) (Table 1) and averages 1.4 Φ (medium grained). Most of the samples are poorly sorted. Gravel averages 2 percent, sand 88 percent, and mud 10 percent.

Overlying this part of the aquifer, from about 323 to 348 ft, is a well-compacted sandy clay and clayey sand that correlates with the upper Steel Creek unit. One particle-size analysis indicates 30 percent sand and 70 percent mud (Table 1). Most of the sand fraction is either medium or coarse grained, but the grains are embedded in the dense matrix.

The uppermost part of the aquifer, from 298 to 323 ft, correlates with the Sawdust Landing Formation and consists of very poorly sorted fine to very coarse quartz sand in a kaolin clay matrix. Matrix content ranges from about 5 to 35 percent and is dense in places. Mean grain size of three particle-size analyses ranges from 2.2 to 0.4 Φ (fine to coarse grained) (Table 1) and averages 1.4 Φ (medium grained). All of the samples are poorly sorted. Gravel averages 4 percent, sand 78 percent, and mud 18 percent.

Hydrologic properties.—The aquifer is divided into four zones on the basis of permeability. The lower part of the aquifer, from 468 to 514 ft, is expected to have only moderate permeability owing to its fine grain size, high clay content, and laminated nature. The middle part of the aquifer, from 348 to 468 ft, is the most permeable, consisting of coarse sand and few clay beds.

Overlying this part of the aquifer, from about 323 to 348 ft (part of the upper Steel Creek unit), is a low-permeability zone that consists of sandy clay and clayey sand. It represents a confining zone in the aquifer. In several cores at SRS it was included as part of the overlying confining unit (Aadland and others, 1995; Gellici and others, 1995). A dense-clay matrix greatly reduces permeability in this interval.

An aquifer zone in the uppermost part of the aquifer (298 to 323 ft) is less compacted and more permeable than the underlying bed and represents a local aquifer zone (Plate 1).

In Orangeburg County, the Crouch Branch aquifer is used by small towns, by farmers for irrigation, and by a power plant at Cope. A 7-day pumping test of the aquifer at Cope indicates a transmissivity of 11,000 ft^2/d (Newcome, 2000), which is basically the same as that calculated for the aquifer in west-central South Carolina (Aadland and others, 1995). A storage coefficient of 2.6×10^{-4} was calculated from the test, and the hydraulic conductivity was estimated at 85 ft/d.

A pumping test made at Holly Hill, in the southeast corner of the county, indicates a transmissivity of only 2,100 ft^2/d (Newcome, 2000), and a hydraulic conductivity value of about 21 ft/d. The lower values reflect changing depositional environments from coarse-grained shallow-water lithofacies in the northern part of the county to fine-grained deep-water lithofacies in the southeastern part of the county.

One monitor well (ORG-393) is completed at the base of the aquifer at the core site (Plate 1). The water-level elevation is +143.6 ft, or 105.7 ft below land surface (measured on July 7, 2006).

Geophysical-log signature.—Resistivity is generally high throughout the aquifer, averaging 160 ohm-meters on the long normal (Plate 1). The upper two zones (upper Steel Creek unit and Sawdust Landing Formation) have lower resistivity values owing to their high clay content. Radiation on the gamma-ray log is low throughout the unit with the exception of the two upper zones.

Meyers Branch Confining System

The Meyers Branch confining system hydraulically separates the Dublin aquifer system from the overlying Floridan aquifer system and is correlated with the Chattahoochee River confining unit of Miller and Renken (1988) (Fig. 2). The system was defined for the hydrogeologic properties of sediments penetrated in type-well P-24 at SRS and named for Meyers Branch, a tributary of Steel Creek near the type well (Aadland and others, 1995). At well P-24 the system is 134 ft thick and consists of clay and silty clay of the Steel Creek Formation (Maastrichtian) and interbedded clay and clayey sand of the Sawdust Landing (Maastrichtian), Lang Syne (lower Paleocene), and Snapp Formations (upper Paleocene). At the ORG-393 core hole the system consists of a single unit, the Crouch Branch confining unit.

Crouch Branch confining unit

The Crouch Branch confining unit overlies and confines the Crouch Branch aquifer and underlies the Gordon aquifer. At ORG-393, the confining unit occurs from 273 to 298 ft and is 25 ft thick. It consists of carbonaceous clay of Paleocene age. Carbonaceous silty clay overlying fine to very coarse clayey sand marks the contact with the underlying Crouch Branch aquifer.

Paleontology and stratigraphic correlation.—Palynomorph assemblages collected from 274.0, 278.1, 289.1, and 298.0 ft in the ORG-393 core and from 277.7 and 298.0 ft in the ORG-430 core all indicate a lower Paleocene age (calcareous nannofossil zones NP1-3). The confining unit is correlated with the Rhems Formation (lower Paleocene, corresponding to calcareous nannofossil zones NP1-3) (Plate 1).

The Crouch Branch confining unit at ORG-393 is correlated with the Crouch Branch confining unit mapped in west-central South Carolina by Aadland and others (1995). It is also correlated with "confining beds" that separate the Black Creek and Black Mingo aquifer systems of Colquhoun and others (1983; see the R. Valentine well on section D-D′, p. 23), with the Rhems Formation (Black Mingo Group) of Colquhoun and others (1983) (Fig. 2), and with the unnamed confining unit that separates the Black Creek and Tertiary sand aquifers of Aucott and others (1987; see well ORG-49 of section C-C′ on Sheet 5).

Lithology and texture.—The confining unit consists of carbonaceous silty clay that is thinly laminated with well-sorted very fine to fine quartz sand and silt. Sand laminations are several millimeters thick. Very fine grained mica and lignite are common in the sand laminations. Pyrite-cemented sand clasts and local pyritized roots/tubes occur in the interval.

Hydrologic properties.—No permeameter tests were made of the cores at Orangeburg. Permeameter tests of 17 clay and sandy clay samples from the confining unit at SRS indicate vertical hydraulic conductivity ranging from 1.81 x 10^{-5} to 9.64 x 10^{-4} ft/d and averaging 1.48 x 10^{-4} ft/d (Bledsoe and others, 1990). Tests of six clayey sand samples have vertical hydraulic conductivities ranging from 1.09 x 10^{-3} to 5.10 x 10^{-1} ft/d and averaging 2.11 x 10^{-2} ft/d. Monitor wells constructed above and below the confining unit at the Orangeburg core site have a head differential of 24.2 ft (Plate 1).

Geophysical-log signature.—Resistivity is low and gamma radiation is relatively high owing to the high clay content of the unit. Long-normal resistivity averages 18 ohm-meters.

Floridan Aquifer System

The Floridan aquifer system overlies the Meyers Branch confining system and is correlated with the Pearl River aquifer and Floridan aquifer system of Miller and Renken (1988) (Fig. 2). In coastal areas of the State it consists of platform carbonate deposits and is a prolific aquifer. Inland, the system transitions from pure carbonates to mixed carbonate/clastic deposits and, farther updip, to purely clastic deposits. The updip clastic equivalents are hydraulically connected to the downdip carbonate rocks and are thus considered part of the Floridan aquifer system.

Sediments penetrated in reference well P-24 at SRS are characteristic of the updip clastic phase of the Floridan aquifer system (Aadland and others, 1995). At well P-24 the system is 216 ft thick and consists of clay, sandy clay, and sand of the Snapp (Paleocene) and Fourmile Formations (lower Eocene), all of the Orangeburg Group (middle Eocene) and Barnwell Group (upper Eocene) sediments, and the overlying Upland unit (Miocene).

At the ORG-393 core hole, the Floridan is transitional between the clastic and carbonate phases of the aquifer system. It includes all sediments from the top of the Meyers Branch confining system to the surficial aquifer zone. The system consists of the Gordon and Upper Three Runs aquifers and the Gordon confining unit.

Gordon aquifer unit

The Gordon aquifer is the lowermost aquifer of the Floridan aquifer system in updip areas. It overlies the Crouch Branch confining unit and is confined by the Gordon confining unit. At ORG-393 the aquifer occurs from 194 to 273 ft and is 79 ft thick. It consists of quartz sand beds of Eocene age. The lower boundary of the aquifer is marked by unconsolidated, fine to very coarse, clayey sand that overlies laminated silty clay and very fine sand of the Crouch Branch confining unit.

Paleontology and stratigraphic correlation— Palynomorph assemblages from 228.8, 248.0, 250.0, 262.1, and 272.0 ft at core hole ORG-393 and from 251.0, 254.9, and 267.7 ft at core hole ORG-430 indicate a lower Eocene age (calcareous nannofossil zone NP-12). Palynomorph assemblages from 211.6 ft at core hole ORG-393 and from 211.6 and 212.3 ft at core hole ORG-430 indicate a lower Eocene age (calcareous nannofossil zones NP12-13). Palynomorph assemblages from 190.2 ft at core hole ORG-393 and from 191.4 ft at core hole ORG-430 indicate an early middle Eocene age (calcareous nannofossil zone NP-14). The aquifer correlates with the Congaree Formation (lower Eocene to early middle Eocene, corresponding to calcareous nannofossil zones NP12-14).

The Gordon aquifer at ORG-393 is correlated with the lower part of the Pearl River aquifer of Miller and Renken (1988), with the Tertiary sand aquifer of Aucott and others (1987), with the Neeses Formation (Orangeburg Group) of Colquhoun and others (1983) (Fig. 2), and with the Gordon aquifer of Aadland and others (1995).

Lithology and texture.—The aquifer is characterized by unconsolidated, moderately to poorly sorted, fine to very coarse and locally gravelly quartz sand and clayey sand. Traces of glauconite are common. Clay matrix is usually less than 10 percent but can be as high as 20 percent and increases with depth. Laminated sandy clay beds, less than 2 ft thick, occur in the aquifer. Mean grain size of five particle-size analyses ranges from 1.3 to 0.7 Φ (medium to coarse grained) (Table 1) and averages 0.9 Φ (coarse grained). All of the samples are poorly sorted. Gravel averages 2 percent, sand 91 percent, and mud 7 percent.

Hydrologic properties.—The Gordon aquifer is not as productive as the Crouch Branch or McQueen Branch aquifers in Orangeburg County or in counties near SRS, reflecting differences in the composition, texture, and thickness of the aquifers. The aquifer is relatively shallow, however, and provides a relatively inexpensive source of good drinking water to small towns and small industries. North and northwest of the core hole, the aquifer thins and is generally not deep enough to be used as a municipal source of drinking water. In these areas, towns usually tap the deeper Crouch Branch aquifer.

A pumping test made about 5 mi east of Bowman (well ORG-345) indicates a transmissivity of 270 ft^2/d (Newcome, 2005), and a hydraulic conductivity of 18 ft/d. The transmissivity value calculated from the test may be low because only the upper 15 ft of the 40-ft aquifer was screened. Transmissivity values in the SRS region are about 3,000 ft^2/d and comparable values can probably be obtained for the aquifer in Orangeburg County.

One monitor well (ORG-430) is completed in the aquifer at the core site (Plate 1). The water-level elevation is +167.9 ft, or 85.1 ft below land surface (measured on July 7, 2006). A downward hydraulic gradient and a head difference of about 19 ft exists between the Gordon and the underlying Crouch Branch aquifer in the Orangeburg area.

Wells drilled for the city of Orangeburg in 1916 were completed in the Gordon aquifer. Most of these wells were drilled in or near the flood plain of the North Fork Edisto River at an elevation 90 to 100 ft lower than that at the core hole; consequently, most of the wells flowed. The wells have since been abandoned, and the Edisto River currently supplies the city.

Geophysical-log signature.—Long-normal resistivity values are generally less in this aquifer than in Cretaceous aquifers (Plate 1), averaging only 80 ohm-meters. This is observed in other core holes and may reflect differences in water chemistry and clay content. Gamma radiation is very low, as is characteristic of the unit in the western part of the Coastal Plain near SRS.

Gordon confining unit

The Gordon confining unit separates the Gordon aquifer from the overlying Upper Three Runs aquifer. At ORG-393, the confining unit occurs from 92 to 194 ft and is 102 ft thick. It consists of marl and fine-grained glauconitic sand of Eocene age. The lower boundary is marked by glauconitic silty clay that overlies fine to coarse sand of the Gordon aquifer.

Paleontology and stratigraphic correlation.—Palynomorph assemblages collected from 180.2 and 183.5 ft at core hole ORG-393 and from 179.6 and 186.6 ft at ORG-430 indicate a middle Eocene age (calcareous nannofossil zone NP-15). Palynomorph assemblages collected from 101.1, 123.1, and 148.5 ft at core hole ORG-393 and from 169.5 ft at core hole ORG-430 indicate a late middle Eocene age (calcareous nannofossil zone NP-16). Calcareous nannofossil assemblages from 101.0, 113.6, 123.0, 128.5, 132.8, 138.5, 143.3, and 148.5 ft at core hole ORG-393 indicate a late middle Eocene age (calcareous nannofossil zone NP-16).

The confining unit comprises parts of three formations that, in ascending order, include: 1) the upper part of the Congaree Formation; 2) the Warley Hill Formation; and 3) and the lower part of the Santee Formation. From 190 to 194 ft the unit consists of the uppermost part of the Congaree Formation (early middle Eocene, corresponding to calcareous nannofossil zone NP-14); from 177 to 190 ft it consists of the Warley Hill Formation (middle Eocene, corresponding to calcareous nannofossil zone NP-15); and from 92 to 177 ft it consists of the Santee Formation (middle middle Eocene to late middle Eocene, corresponding to calcareous nannofossil zone NP-16) (Plate 1). The upper part that correlates with the Santee Formation is similar in lithology and age to the Blue Bluff unit described by Fallaw and Price (1995) at SRS.

The Gordon confining unit at ORG-393 is correlated with the middle part of the Pearl River aquifer of Miller and Renken (1988), with the Santee Limestone (Orangeburg Group) of Colquhoun and others (1983) (Fig. 2), with the middle part of the Tertiary sand aquifer of Aucott and others (1987), and with the Gordon confining unit mapped in west-central South Carolina by Aadland and others (1995).

Lithology and texture.—The confining unit is characterized by moderately indurated, very fine to fine quartz sand in a calcareous clay matrix that is weakly cemented with calcium carbonate. Numerous thin beds, up to 0.5 ft in thickness, are tightly cemented with calcium carbonate. Bivalve, gastropod, and bryozoan shell fragments are common and can constitute up to 20 percent of the unit. Calcareous sediments decrease significantly toward the base and are absent in the lower 6 ft where the unit consists only of silty clay.

Traces of glauconite and phosphate occur throughout the unit but become increasingly concentrated toward the bottom (160 to 194 ft) where they compose up to 60 percent of the unit. From 160 to 177 ft (lower part of the Santee Formation) the unit is phosphatic marl, consisting of very fine to fine quartz sand in a calcium carbonate matrix containing abundant microfossils and megafossils. Rounded phosphate grains and glauconite constitute up to 60 percent of this zone. From 177 to 190 ft (Warley Hill Formation) the unit is a glauconitic sandy clay and marl consisting of fine to very coarse-grained quartz sand in a 60- to 70-percent clay matrix that is cemented with calcium carbonate.

Mean grain size of four particle-size analyses ranges from 4.1 to 2.7 Φ (silt to fine grained) (Table 1) and averages 3.4 Φ (very fine grained). Samples range from well sorted to very poorly sorted. Sand content averages 46 percent, most of which is very fine, and mud averages 52 percent. Gravel in the form of shell fragments composes about 2 percent of the samples.

Hydrologic properties.—No permeameter tests were made of the Orangeburg core, but three tests of the confining unit at well-cluster sites C-6 (core hole BRN-349) and C-7 (core hole ALL-358) in Barnwell and Allendale Counties, S.C., (Gellici and others, 1995) showed vertical hydraulic conductivity ranging from 1.22×10^{-4} to 1.95×10^{-4} ft/d, and averaging 1.51×10^{-4} ft/d. Monitor wells constructed above and below the confining unit at the Orangeburg core site have a head differential of 55.4 ft (Plate 1).

Geophysical-log signature.—Resistivity averages 13 ohm-meters on the long-normal log. A high-radiation zone (gamma-ray spike) at the base of the unit (Plate 1) is a characteristic feature that is observed in other wells in Orangeburg County and in other parts of the Coastal Plain. It is often used as a marker bed for the base of the Santee Formation and for the Warley Hill Formation. This zone occurs from 160 to 194 ft. Elevated radiation levels are caused by the high clay content and by glauconite, which can constitute up 30 percent of the unit.

Upper Three Runs aquifer unit

The Upper Three Runs aquifer overlies the Gordon confining unit and underlies the surficial aquifer zone. At ORG-393, the aquifer occurs from 22 to 92 ft and is 70 ft thick. It consists of limestone and clayey quartz sand of Eocene and Oligocene age. A slightly sandy shelly limestone that overlies fine-grained calcareous, sandy clay (marl) marks the boundary with the underlying Gordon confining unit.

Paleontology and stratigraphic correlation.—Palynomorph assemblages collected from 68.2, 78.3, 85.0, and 90.1 ft at ORG-393 and from 78.5 ft at ORG-430 indicate a late middle Eocene age (upper part of calcareous nannofossil zone NP-16). Calcareous nannofossil assemblages from 68.1, 73.1, 78.2, 81.0, and 90.0 ft at ORG-393 indicate a middle middle Eocene age (lower part of calcareous nannofossil zone NP-16). Palynomorph assemblages collected from 43.2 and 48.5 ft at ORG-393 and from 46.1 ft at ORG-430 indicate a lower to upper Oligocene age (calcareous nannofossil zones NP24-25).

The lower part of the aquifer, from 49 to 92 ft, correlates with the Santee Formation (middle middle Eocene to late middle Eocene, corresponding to calcareous nannofossil zone NP-16) and the upper part, from 22 to 49 ft, correlates with an unrecognized Oligocene unit that may be correlated with either the Tobacco Road Sand (see Huddlestun and Hetrick, 1978), with the Ashley Formation (see Hazel and others, 1977), or with the Tiger Leap Formation (see Weems and Edwards, 2001).

The Upper Three Runs aquifer at ORG-393 is correlated with the upper part of the Floridan aquifer system of Miller and Renken (1988), with the McBean Formation (Orangeburg Group) of Colquhoun and others (1983) (Fig. 2), with the Floridan aquifer system of Aucott and others (1987), and with the Upper Three Runs aquifer mapped in west-central South Carolina by Aadland and others (1995).

Lithology and texture.—The aquifer consists of shelly limestone and clayey sand of the Santee Formation and clayey sand and sandy clay of the unnamed Oligocene unit (see a detailed discussion of the lithology in the "ORG-393 Floridan aquifer zone" section below).

Hydrologic properties.—An aquifer zone, herein called the "ORG-393 Floridan aquifer zone", occurs in the aquifer and is described below.

Geophysical-log signature.—Low radiation levels on the gamma-ray log from moldic limestone beds (83 to 92 ft) indicate a low clay content. Radiation values increase in clastic beds of the Santee Formation and in the unnamed Oligocene unit and are particularly high at the base of the Oligocene unit (Plate 1). Resistivity values could not be obtained from most of the aquifer because surface casing was installed to prevent caving during the coring operation.

ORG-393 Floridan aquifer zone.—The "ORG-393 Floridan aquifer zone" is an informal name for a zone that occurs at the base of the Upper Three Runs aquifer at the ORG-393 core hole. The hydraulic continuity of the zone is thought to be limited and, therefore, it is not formally named. It overlies the Gordon confining unit and occurs from 49 to 92 ft. This zone appears to be in the same stratigraphic interval as the middle Floridan aquifer of Gawne and Park (1992) that was mapped in Beaufort County, S.C., but it is unclear if they are hydraulically connected and constitute a single aquifer unit.

The lower part of the zone, from 66 to 92 ft, is correlated with the Santee Formation and consists of two moldic shelly limestone beds separated by fine-grained marl (Plate 1). One limestone bed occurs from 83 to 92 ft and consists of impure micritic shelly limestone and 5 to 10 percent fine to coarse quartz sand. Framework clasts consist of whole and broken shells of mollusks, pelecypods, and bryozoans weakly cemented with calcium carbonate. Parts of the bed have a very fragmented texture and other parts are well-indurated. Moldic pores account for most of the porosity in the bed. Porosity is reduced in places by recrystallized sparry calcite that lines moldic pores.

Fine-grained marl occurs from 76 to 83 ft and consists of 10 to 20 percent fine quartz sand and 80 to 90 percent calcareous clay. Irregular calcite-cemented zones, up to 0.5 ft in thickness, occur in the marl. Permeability is expected to be very low in this interval. A particle-size analysis from the bed indicates a mean grain size of 4.3 Φ (silt). Sand content is 20 percent and mud content 80 percent.

A second limestone bed that occurs from 66 to 76 ft consists of fine-grained impure limestone with about 10 percent quartz sand and 5 percent clay. This bed is slightly moldic and does not appear to be as permeable as the lower bed. A clayey sand bed that is weakly cemented with calcium carbonate and that contains glauconite, phosphate, and sparse silicified shells caps the unit from 65 to 66 ft.

The upper part of the zone, from 49 to 66 ft, is probably correlated with clastic age-equivalent beds of the Santee Formation (either with the Tinker Formation of Fallaw and Price (1995) or with the Orangeburg District bed as defined by Dockery and Nystrom, 1992); however, the interval was barren of fossils. This part of the aquifer zone is characterized by very fine to coarse quartz sand and clayey sand. Particle-size analyses of two samples indicate a mean grain size of 3.6 and 3.2 Φ (both very fine grained) (Table 1). The samples are moderately to poorly sorted. Sand averages 70 percent and mud 30 percent. Permeability is low, owing to the very fine grain size and high clay content.

Overlying the aquifer zone is a silty clay bed (41 to 49 ft) that occurs at the base of the unnamed Oligocene unit (Plate 1). This bed may be a confining zone that separates the ORG-393 Floridan aquifer zone from the overlying surficial aquifer zone. No monitor wells, however, are completed in the surficial zone to verify this.

This aquifer zone at Orangeburg probably represents the farthest inland extent of permeable limestone beds of the Floridan aquifer system in the area. About 10 miles northwest of ORG-393, at core hole ORG-256, no limestone is present in the Coastal Plain sequence. There, the Santee Formation consists only of sand and clayey sand (equivalent to the Tinker Formation of Fallaw and Price, 1995).

Although a thick (111 ft) limestone section of the Santee Formation is present at the Orangeburg core hole, only moldic limestone beds in the upper 26 feet of the formation are permeable. Porosity and permeability of these beds are probably variable, owing to changes in the dissolution and precipitation of carbonate cement. As such, the aquifer zone may be discontinuous and patchy in the vicinity of Orangeburg. Hydraulic characteristics of the zone are unavailable but, where present, the moldic beds are known to produce enough water for individual households in the Orangeburg area.

One monitor well (ORG-431) is constructed in the zone at the core site and is completed as an open hole in the moldic limestone beds of the Santee Formation (Plate 1). The water-level elevation is +223.3 ft, or 29.7 ft below land surface (measured on July 7, 2006). A downward hydraulic gradient exists between the Middle Floridan aquifer and the underlying Gordon aquifer.

Surficial aquifer zone

At the Orangeburg core hole, a surficial aquifer zone occurs from 0 to 22 ft. Sediments from the zone could not be dated but are thought to be of Quaternary age.

The zone consists of poorly sorted, very fine to very coarse, clayey sand and gravel. Accessory minerals include opaque heavy minerals, mica, and feldspar. Mean grain size of two particle-size analyses ranges from 3.8 to 3.3 Φ (very fine grained) (Table 1) and averages 3.5 Φ. The samples are moderately and poorly sorted. Sand averages 61 percent and mud 39 percent. Permeability is low, owing to the very fine grain size and the high clay content of the zone. No hydraulic data are available for the zone and its degree of hydraulic connection to the underlying Upper Three Runs aquifer is unknown.

HYDROGEOLGIC SECTIONS

Two hydrogeologic sections were drawn to traverse the county in SW-NE and NW-SE directions, strike and dip oriented, respectively (see Fig. 1 and Plates 2 and 3). The vertical scale on the sections is 1 inch to 200 feet, and the horizontal scale is 1 inch to 4 miles, the same scales used by Aucott and others (1987) on their sections. A third section (C-C′; Plate 4) correlates the hydrostratigraphy at ORG-393 to core hole BRN-335 at SRS (designated at SRS as the P-21 core hole). To reduce the size of the section, the horizontal scale was doubled to 1 inch to 8 miles. Stratigraphic boundaries are listed in Table 2. All latitude and longitude coordinates of well locations are referenced to the North American Datum of 1927 (NAD27).

Section A-A′ (Plate 2) includes test hole ORG-380, water well ORG-262, and core hole ORG-393. Test hole ORG-380 (latitude 33º 22′ 07″ N; longitude 81º 01′ 44″ W), near Cope, S.C., was drilled in 1994 by McCall Brothers Drilling Company (Charlotte, N.C.) for the South Carolina Electric and Gas Company to evaluate ground-water availability for a coal-fired power plant. Geophysical-log depth is 1,017 ft, and land-surface elevation is +177 ft. Drill cuttings were collected and described by Constance Gawne of SCDNR and by personnel with McCall Brothers. Well ORG-262 (latitude 33º 31′ 35″ N; longitude 80º 34′ 17″ W), in Elloree, S.C., was drilled for the town in 1984 by Grosch Drilling and Exploration Company (Dublin, Ga.) and is still in operation. Log depth is 956 ft and land-surface elevation is +165 ft. Drill cuttings were collected and described by personnel at Grosch.

Section B-B′ (Plate 3) includes water well ORG-108 and core holes ORG-256 and ORG-393. Well ORG-108 (latitude 33º 20′ 55″ N; longitude 80º 40′ 47″ W), at Bowman, S.C., was drilled for the town in 1980 by Virginia Well and Supply Company (Atlanta, Ga.) and is still in operation. Geophysical-log depth is 1,193 ft, and land-surface elevation is +142 ft. Drill cuttings were collected and described by the company and by personnel with the South Carolina Water Resources Commission. Core hole ORG-256 (latitude 33º 36′ 36″ N; longitude 81º 00′ 30″ W), near the town of Wolfton, S.C., was drilled in 1982 by the USGS and was described by David C. Prowell (USGS), Joseph A. Gellici (SCDNR), and Karen E. Agerton (SCDNR). Core depth is 326 ft, and land-surface elevation is +285 ft. The borehole was completed as a monitor well.

Section C-C′ (Plate 4) includes core holes ORG-393 and BRN-335. Core hole BRN-335 (latitude 33º 08′ 48″ N; longitude 81º 36′ 27″ W) is in Barnwell County at the southern end of the Savannah River Site. Geophysical-log depth is 1,148 ft, core depth is 1,152 ft, and land-surface elevation is +207 ft. Seven monitor wells were completed at the site (Plate 4). David C. Prowell of the USGS described the core and the hydrostratigraphy was determined by Aadland and others (1995).

Seven tracks of information are provided at each core hole and six tracks at each water well. Beginning at the left, track 1 lists geologic formations, which are allostratigraphic units (i.e. unconformity-bounded units), as described above. David C. Prowell (USGS) identified the formation contacts by using paleontology results, core analyses, and geophysical logs. Accurate formation contacts could not be determined at the water wells, and only the Cretaceous/Tertiary (K/T) contact is shown. The K/T was estimated from geophysical logs, driller's logs (drill cuttings), and projections from surrounding core holes. Track 2 is an overlay of the spontaneous-potential log (units are millivolts, mvol) and the natural gamma-radiation log (units are counts per second, cps). Track 3 is elevation, in feet, relative to mean sea level. Track 4 is depth, in feet, below land surface. Track 5 is a lithology log of the cores. Lithology was estimated from drill cuttings and geophysical logs at the water wells. A key to the lithology symbols is provided on Plate 1. Track 6 is an overlay of the single-point resistance log (units are electrical resistance, ohms) and the 64-inch, long-normal resistivity log (units are electrical resistivity in ohm-meters, ohm-m). Track 7 shows screen locations of monitor wells at the core sites and of the water wells.

The sections are registered to sea level. Only the ORG-393 core hole reached basement. Depth to basement at other wells was estimated from the map of Prowell and others (2000). No single-point resistance log was available for wells ORG-256 and ORG-262, and none is provided on the section. No spontaneous-potential log or long-normal resistivity log was available for well ORG-108 and neither is provided on the section.

Hydrogeologic Section A-A′

Section A-A′ (Plate 2) is a strike-oriented hydrogeologic section that extends from the western part of the county near Cope to the eastern part of the county near Elloree (Fig. 1). It depicts the thickness and continuity of aquifers and confining units in a SW-NE direction.

The basal Gramling confining unit is continuous and projected to be about 150 to 200 ft thick across the area (Table 2; Plate 2). Overlying the Gramling is the McQueen Branch aquifer, which is thick (250 ft) and continuous

Table 2. Baseline stratigraphy used in this report

Well number	ORG-393	BRN-335	ORG-108	ORG-256	ORG-262	ORG-380
Elevation (ft above sea level)	253	207	142	285	165	177
Hydrostratigraphy						
Surficial aquifer zone	0-22		0-20		0-35	
Upper Three Runs aquifer	22-92	0-162	20-110	0-70	35-50	0-80
Gordon confining unit	92-194	162-232	110-235	70-82	50-104	80-205
Gordon aquifer	194-273	232-326	235-280	82-142	104-150	205-250
Crouch Branch confining unit	273-298	326-472	280-330	142-212	150-195	250-300
Crouch Branch aquifer	298-514	472-705	330-615	212-*400*	195-531	300-544
McQueen Branch confining unit	514-693	705-789	615-800	*400-460*	531-665	544-712
McQueen Branch aquifer	693-977	789-1,021	800-1,120	*460-730*	665-*957*	712-1,000
Gramling confining unit	977-1,117	1,021-*1,200*	1,120-*1,400*	*730-800*	*957-1,195*	1,000-*1,177*
Allostratigraphy						
Unnamed Quaternary unit	0-22					
Unnamed Oligocene unit	22-49	0-50		0-25		
Dry Branch Fm		50-144				
Santee Fm	49-177	144-232		25-78		
Warley Hill Fm	177-190	232-240		78-85		
Congaree Fm	190-273	240-324		85-142		
Chicora Fm		324-363				
Lang Syne Fm		363-419		142-177		
Rhems Fm	273-298	419-445		177-185		
Cretaceous/Tertiary contact (K/T)	298	445	330	185	195	300
Sawdust Landing Fm	298-323	445-452		185-219		
Upper Steel Creek unit	323-398	452-518		219-274		
Middle Steel Creek unit	398-446	518-574		274-312		
Lower Peedee unit	446-468	574-598		312-321		
Upper Donoho Creek unit	468-557	598-725		321-371		
Middle Donoho Creek unit	557-606					
Bladen Fm	606-670	725-769				
Coachman Fm	670-711	769-810				
Cane Acre Fm	711-895	810-1,020				
Cape Fear Fm	895-1,117	1,020-*1,200*				
Undifferentiated Cretaceous				*371-800*		
Basement	1,117-1,138	*1,200-1,200*	*1,400-1,400*	*800-800*	*1,195-1,195*	*1,177-1,177*

Units are in feet, measured from land surface.
Numbers in italic are estimated (geophysical logs and cores did not penetrate unit).

from Cope to Orangeburg. A confining zone consisting of sandy clay splits the aquifer at Elloree. This zone has a low resistivity and high radiation trace on geophysical logs and can be mapped through Summerton and into Manning, about 24 miles east of Elloree. Extrapolation to a core hole at Florence (FLO-274) suggests that it is correlated with the Shepherd Grove Formation (Upper Cretaceous; upper Santonian to lower Campanian, corresponding to calcareous nannofossil zone CC-17; see Gohn, 1992). The upper part of the McQueen Branch aquifer at Elloree is interpreted as the Cane Acre Formation. Geophysical logs indicate that it has a higher clay content and is less permeable than at the ORG-393 core. The lower part of the aquifer (below the confining zone) correlates with either the upper part of the Cape Fear Formation or possibly with strata of Santonian age. Several small towns, such as Elloree and Manning, tap this lower part of the aquifer, which can yield more than 500 gpm to a well. The well at Elloree (ORG-262), which is screened in both parts of the aquifer (Plate 2), was pumped at 800 gpm for 4.5 hours and had a drawdown of about 150 ft.

Overlying the McQueen Branch aquifer is the McQueen Branch confining unit, which is continuous and about 150 ft thick across the area. Above the confining unit is the Crouch Branch aquifer, which is also split by a confining zone at Elloree. A thick (130 ft) sandy clay layer, marked by a prominent low-resistivity zone on the long-normal log, occurs in the aquifer that is absent at the ORG-393 core. The upper part of the aquifer (above the confining zone) is interpreted as the Sawdust Landing Formation and the upper Steel Creek unit, and the lower part as the upper Donoho Creek unit. The lower Peedee and middle Steel Creek units probably compose the confining zone at Elloree.

Overlying the Crouch Branch aquifer is the Crouch Branch confining unit, which is mapped as a continuous unit across the area but which may be breached or absent in places because of its relative thinness (30 to 50 ft). The overlying Gordon aquifer is continuous and thins in either direction away from Orangeburg. Elevated radiation levels on the gamma-ray log (Plate 2) mark the base of the Gordon confining unit, which is also continuous across the area. The Upper Three Runs aquifer is continuous and also thins towards the northeast. It consistently contains shelly limestone beds at its base, a possible continuation of the ORG-393 Floridan aquifer zone (Santee Formation) as described above.

Hydraulic properties of the aquifers change from one side of the county to the other, reflecting changes in the depositional history of the Coastal Plain. This is especially true of the Cretaceous aquifers—the Crouch Branch and McQueen Branch. The eastern side is transitional between coarse-grained deltaic lithologies that are found in the western part of the county and at SRS and fine-grained distal-deltaic and continental shelf lithologies that are found in neighboring Dorchester and Berkeley Counties to the east and southeast.

Hydrogeologic Section B-B′

Section B-B’ (Plate 3) is a dip-oriented hydrogeologic section that extends from the northern part of the county near Wolfton to the southern part near Bowman (Fig. 1). It depicts the thickness and continuity of aquifers and confining units in a NW-SE direction.

The basal Gramling confining unit is continuous across the area (Plate 3) but thins to the northwest at Wolfton where it is projected to be about 70 ft thick. A thick (100 ft) clayey sand bed divides the McQueen Branch aquifer downdip at Bowman and is probably the same confining zone observed in the aquifer at Elloree. The McQueen Branch confining unit is projected to thin considerably to the northwest at Wolfton. Farther updip, at a core hole in Swansea (LEX-844), the confining unit is absent.

The Crouch Branch aquifer is projected to be thick and continuous to the northwest at Wolfton, but it splits to the southeast at Bowman. Pumping tests show a significant drop in hydraulic conductivity and transmissivity in the Holly Hill area, about 15 miles east of Bowman, indicating a change in grain size and clay content. The Crouch Branch confining unit is 30 to 70 ft thick across the area.

The Gordon aquifer thins to the southeast and may be absent downdip at Bowman as indicated by relatively high radiation levels on the gamma-ray log. The Gordon confining unit thins significantly at Wolfton, where it consists only of interbedded glauconitic sand and clay of the Warley Hill and Santee Formations. Marl beds (Santee Formation) that constitute most of the confining unit at the ORG-393 core are absent updip at the Wolfton core. The Upper Three Runs aquifer is limy downdip at the Bowman well where it probably transitions to the carbonate phase of the Floridan aquifer system. Moldic limestone beds that occur at the base of the aquifer at the ORG-393 core hole (the ORG-393 Floridan aquifer zone) are absent updip at the Wolfton core.

Hydrogeologic Section C-C′

Section C-C′ (Plate 4) was drawn to illustrate the continuity and correlation of hydrostatigraphic units described at SRS (Aadland and others, 1995) with those described herein. The hydrostratigraphic designations shown at core hole BRN-335 are the same as those used in Aadland’s report. Generally, excellent correlation occurs among all units.

The McQueen Branch confining unit is thinner at BRN-335 because the middle Donoho Creek unit, which is 49 ft thick at ORG-393, is absent. Significant clay beds occur at the top of the Crouch Branch aquifer at SRS that are absent at Orangeburg. The Crouch Branch confining unit is thicker at SRS because it includes the Sawdust Landing Formation, part of the upper Steel Creek unit, and the Chicora Formation (upper Paleocene, corresponding to calcareous nannofossil zones NP6-9). No upper Paleocene strata occur at Orangeburg. The Upper Three Runs aquifer is thicker at SRS where it includes the Dry Branch Formation (upper Eocene, corresponding to calcareous nannofossil zones NP19-20), a formation that is absent at Orangeburg.

DISCUSSION

Core hole ORG-393 serves as a benchmark hydrostratigraphic test hole for the central region of the South Carolina Coastal Plain. Hydrostratigraphic units are delineated on the basis of relative permeability by using core descriptions, geophysical logs, particle-size analyses, and hydrostatic-head data and are correlated to other wells on the basis of hydraulic continuity by using biostratigraphic and allostratigraphic data.

The use of cores and geophysical logs in conjunction with biostratigraphic and allostratigraphic data greatly improves hydrostratigraphic correlations across the Coastal Plain. These data, however, should be supplemented with additional hydraulics data, such as pumping and permeameter tests, and with hydrostatic-head data to better understand the flow system. Additional monitor wells are needed at this core site, and at other core sites, to determine hydraulic gradients, to determine if the aquifers delineated are hydraulically continuous throughout their entire thickness, and to determine if the confining units have been correctly identified and are capable of supporting heads while being stressed by pumping. Aquifer transmissivity, horizontal and vertical hydraulic-conductivity values, and leakage coefficients are needed to better characterize the units.

In the past, geologists working in South Carolina chose to name hydrogeologic units after geologic formations. Over time, as additional data were collected, new formations were identified and named, old formations were abandoned, revised, or raised to group status and the stratigraphy was thereby improved. Such changes made to the geologic nomenclature required that changes also be made to the hydrogeologic nomenclature. As an example of this, in the past the strata in updip regions of the Coastal Plain were incorrectly correlated with the Tuscaloosa Formation and aquifers were correspondingly (and incorrectly) named the Lower and Upper Tuscaloosa aquifers. The names have since been abandoned and the aquifers are currently named after the Middendorf and Black Creek Formations. It now appears that these names will have to change in light of new information regarding the age and distribution of the Middendorf and Black Creek Formations.

To avoid this problem in the future, members of the South Carolina Hydrostratigraphic Subcommittee (see Burt, 1987a and 1987b) proposed that a hydrostratigraphic nomenclature be developed that is independent of the geologic nomenclature. Aadland and others (1995) implemented such a nomenclature at SRS, which is adopted in this report. This new nomenclature, however, is not widely recognized outside of SRS. In this report, careful attention was paid to relating the new aquifer names to the more commonly used names of Colquhoun and others (1983) and Aucott and others (1987). Direct correlation between the various nomenclatures is not always possible, however, because interpretations of the stratigraphy have been revised over the years and different investigators have different opinions about the stratigraphy. For example, Colquhoun and others (1983), not having the benefit of a core hole, did not recognize the Cape Fear Formation at Orangeburg, which forms the Gramling confining unit of this report. The Gramling confining unit correlates with what they labeled "crystalline rocks of the Piedmont." This example points to one of several problems relating the two stratigraphic nomenclatures and frameworks. The extensive use of paleontology in this report puts a "time stamp" on formations that compose the hydrostratigraphic units and should make future correlations more exact by eliminating some of the subjectivity of interpolating between wells that are spaced many miles apart.

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APPENDIX

Core description of ORG-393.

Core was described by David C. Prowell of the USGS.

Depths are reported in feet below land surface.

See Plate 1 for a graphic lithology column.

ORG-393 **Depth (ft)**

Surficial aquifer zone

(Unnamed Quaternary unit)

– Clayey sand, moderate yellowish brown (10-YR-5/4) and moderate reddish brown (10-R-4/6) to moderate reddish orange (10-R-6/6), fine to very coarse quartz sand in a 20 to 40 percent clay matrix, poorly sorted; trace gravel (up to 20 mm); trace feldspar; local iron staining; poorly bedded with some evidence of cross beds (15 to 20 degrees) in clay- and silt-rich beds; poorly consolidated 0-21.6

Upper Three Runs aquifer

(Unnamed Oligocene unit)

– Clayey sand, dark yellowish orange (10-YR-6/8), very fine to medium quartz sand and beds of fine to very coarse quartz sand in a 5 to 25 percent clay matrix, moderately to poorly sorted; 2 to 3 percent mica; trace feldspar; mottled texture; crudely bedded in fining-upwards sequence; poorly consolidated 21.6-40.5

– Silty clay, dark gray (N-3) with common dark yellowish orange staining (10-YR-6/6), very fine to fine quartz sand and silt in a 50 to 70 percent clay matrix, well sorted; 1 to 2 percent mica; trace pyrite as concretions and trace lignite/carbon clasts; thinly laminated beds; poorly consolidated 40.5-49.4

(Santee Formation, clastic phase)

– Clayey sand, dark yellowish orange (10-YR-6/6), fine to coarse quartz sand near top of interval and very fine to fine sand near base, 5 to 25 percent clay matrix, moderately to well sorted; 1 to 2 percent mica; local blebs of carbon/manganese; local very thin clay stringers; crudely bedded with hint of cross bedding; poorly consolidated 49.4-65.0

(Santee Formation, carbonate phase)

– Marl, pale olive (10-Y-6/2), very fine to fine quartz sand and clay in a calcium carbonate matrix, well sorted; 1 to 2 percent glauconite and phosphate (?); sparse silicified shells 65.0-66.3

– Limestone, yellowish gray (5-Y-7/2); impure limestone with 5 to 10 percent quartz sand, 5 to 10 percent shell fragments, and 5 percent clay, poorly to moderately sorted; sparse mollusk (?) shells extend across core diameter; local iron oxidation; weakly indurated except for local 0.5 ft beds of purer calcium carbonate 66.3-76.0

– Marl, greenish gray (5-G-6/1) and yellowish gray (5-Y-7/2), very fine to fine quartz sand and silt (10 to 20 percent) in a calcareous clay matrix (80 to 90 percent); 1 to 2 percent mica; sparse phosphate and shell fragments; trace glauconite; well-bedded 76.0-82.5

– Limestone, yellowish gray (5-Y-8/1) to white (N-9), impure limestone with 5 to 10 percent quartz sand and 20 to 30 percent shell fragments, poorly sorted; local calcium carbonate cemented beds (0.3 to 0.5 ft), otherwise sediment is broken into coarse granules; shells consist of mollusks, pelecypods, bryozoans, and unidentified microfossils; fragmented texture 82.5-91.5

Gordon confining unit

(Santee Formation, carbonate phase)

– Marl, grayish olive green (5-GY-3/2), light olive gray (5-Y-5/2) and greenish gray (5-GY-6/1), very fine to fine quartz sand (40 percent), clay (35 percent), and shell fragments (20 percent) in a calcareous matrix; megafossils are bivalves, gastropods, and bryozoans; sparse bone fragments and shark teeth; trace lignite, glauconite, and phosphate; phosphate especially abundant from 146 to 153 ft; large brown bivalves common from 153 to 158 ft; generally moderately to well-cemented with calcium carbonate; local hard layers (0.3 to 0.4 ft) of calcium carbonate; common burrows; well-bedded with thin laminations in clayey zones 91.5-158.0

– Phosphatic marl, marl as described above but with a significant increase in phosphate and glauconite; phosphate and glauconite increase with depth composing 50 to 60 percent of the core towards the base of the interval 158.0-177.4

(Warley Hill Formation)

– Marl, olive gray (5-Y-3/2), fine to very coarse quartz sand and silt in a 60 to 70 percent clay matrix; weak reaction with hydrochloric acid; 5 to 30 percent glauconite; common very fine carbonaceous matter; sparse shell fragments; well laminated; well compacted 177.4-186.5

– Clayey sand, olive gray (5-Y-3/2), fine to very coarse quartz sand in a 20 to 30 percent clay matrix, poorly sorted; 5 to 10 percent glauconite; sparse gravel (3 to 4 mm); trace blue quartz and carbonaceous matter; massive 186.5-189.5

(Congaree Formation)
– Silty clay, grayish green (10-GY-5/2), very fine to fine quartz sand and silt in a 60 percent clay matrix, well sorted; 2 to 4 percent mica; 1 to 2 percent glauconite; well laminated 189.5-194.3

Gordon aquifer
(Congaree Formation)
– Clayey sand, olive gray (5-Y-3/2), fine to coarse quartz sand in a 10 to 20 percent clay matrix, moderately sorted; sparse gravel (2 to 3 mm); trace glauconite; weak reaction with hydrochloric acid; massive 194.3-208.0
– Laminated sand and clay, dark greenish gray (5-GY-4/1) to light olive gray (5-Y-5/2), fine to very coarse quartz sand and gravel in a 5 percent clay matrix, poorly sorted; trace garnet, blue quartz, monazite and rutilated quartz; trace lignite and carbonaceous clay; thinly laminated cross-bedded clay and fine sand beds; loose to moderately compact 208.0-212.5
– Interbedded sand and clay, same as described above but thickly bedded 212.5-228.0
– Laminated sand and clay, same as described above but thinly bedded 228.0-229.8
– Clayey sand, light olive gray (5-Y-5/2), fine to very coarse quartz sand and gravel in 5 percent clay matrix (grain size coarsens with depth), poorly sorted; trace garnet, blue quartz, monazite, rutilated quartz, and glauconite; common lignite/carbonaceous clay; thinly laminated cross-bedded clay and fine sand beds; loose to moderately compact 229.8-272.7

Crouch Branch confining unit
(Rhems Formation)
– Laminated sand and clay, grayish black (N-2), very carbonaceous clay with 10 percent silt, locally interbedded with 1 to 4 mm thick, fine to very fine quartz sand, well sorted; common lignite and mica; low-angle cross beds locally coated with fine lignite; local pyritized roots/tubes and pyrite-cemented sand clasts; well laminated 272.7-298.2

Crouch Branch aquifer
(Sawdust Landing Formation)
– Clayey sand, light blue (5-B-7/6) to greenish gray (5-G-6/1), fine to very coarse quartz sand in a 10 to 20 percent dense clay matrix, poorly sorted; 1 to 2 percent mica; trace feldspar, rutilated quartz, garnet, and monazite; common granular pyrite; very dense and massive 298.2-308.0
– Clayey sand, same as described above except occurring as fining-upwards sequences of very coarse to fine sand and lacking the dense clay matrix 308.0-323.3
(upper Steel Creek unit)
– Sandy clay, light gray (N-8), fine to coarse quartz sand (20 to 50 percent) in a dense clay matrix (50 to 80 percent); 2 to 4 percent mica; trace rutilated quartz; slightly carbonaceous; evidence of carbonized roots and desiccation cracks; dense and indurated 323.3-330.0
– Clayey sand, very light gray (N-8) with grayish orange (10-YR-7/4) staining, similar to that described above except with 70 to 80 percent sand in a stiff clay matrix, very poorly sorted; 5 to 7 percent mica; local gravel (up to 3 mm); grain size coarsens with depth; dense and indurated 330.0-348.0
– Sand, very light gray (N-8), fine to coarse quartz sand in a 0 to 5 percent clay matrix, poorly sorted; grain size coarsens with depth; 2 to 4 percent mica and locally very micaceous with some grains up to 3 mm; lower 7 feet of interval contains common gravel (up to 5 mm) and white clay balls (up to 8 mm); trace monazite and lignite; low-angle cross beds in thin layers; poorly consolidated 348.0-365.2
– Interbedded sand and clay, similar to that described above except with alternating beds of sand and carbonaceous clay; sand beds are light gray (N-7) and are 0.2 to 5 feet thick, and clay beds are medium dark gray (N-4) and are 0.1 to 0.5 feet thick; the interval is predominately sand; poorly consolidated 365.2-398.0
(middle Steel Creek unit)
– Interbedded sand and clay, similar to that described above except that sand beds are thinner (0.2 to 3 feet thick) and carbonaceous clay seams are increasingly present in the sand beds; lignite and pyrite also increase in this interval; poorly consolidated 398.0-423.0
– Clayey sand, light olive gray (5-Y-6/1), fine to very coarse quartz sand in a 5 to 10 percent clay matrix, poorly sorted; trace pyrite and lignite clasts; trace gravel; poorly consolidated 423.0-433.5
– Sand, olive gray (5-Y-4/1), fine to medium quartz sand in a 5 to 10 percent clay matrix, moderately to well sorted; local gravel (up to 2 mm); trace lignite and pyritized lignite; possible burrows; massive; poorly consolidated 433.5-444.7

– Clayey sand, dark gray (N-3), very fine to fine quartz sand with many 20 mm flattened clay clasts; 5 percent mica; very unique; possible lag bed 444.7-446.0

(lower Peedee unit)

– Laminated sand and clay, sand layers are grayish green (5 GY-6/1) and clay layers are dark gray (N-3), very fine to fine quartz sand laminated with thin (2 to 10 mm) beds of micaceous carbonaceous clay (up to 20 percent); 5 to 8 percent mica; trace lignite; well laminated 446.0-449.5
– Sand, light gray (N-7), fine to very coarse quartz sand in a 0 to 5 percent clay matrix, poorly sorted; 1 to 3 percent mica; trace lignite and pyritized lignite; trace rutilated quartz; massive texture 449.5-455.0
– Laminated sand and clay, light olive gray (5-Y-6/1), very fine to fine quartz sand laminated with micaceous and carbonaceous clay, well sorted; 4 to 5 percent mica; trace glauconite and pyrite; sparse lignite fragments (up to 15 mm); well laminated with 3 to 8 mm clay layers separated by 20 to 50 mm sand layers 455.0-457.5
– Glauconitic sand, light olive gray (5-Y-6/1), fine to very coarse quartz sand in a 0 to 5 percent clay matrix, poorly sorted; 1 to 3 percent mica; trace glauconite; local lignitic fragments (up to 3 mm) and pyritized lignite; possible in-situ weathered feldspars and/or white clay blebs; massive texture; poorly consolidated 457.5-468.0

(upper Donoho Creek unit)

– Interbedded sand and clay, sand layers are light olive gray (5-Y-6/1) and clay layers are dark gray (N-3), very fine to fine quartz sand laminated with thin layers of carbonaceous clay, well sorted; some sand beds consist of fine to very coarse sand; 5 to 8 percent mica; trace pyrite; well laminated with 3 to 5 mm clay layers and 10 to 30 mm sand layers 468.0-513.8

McQueen Branch confining unit

(upper Donoho Creek unit)

– Silty clay, dark greenish gray (5-GY-4/1), very fine to fine quartz sand and silt in a 30 to 40 percent clay matrix, well sorted; 2 to 5 percent mica; trace glauconite, pyrite, lignite, and phosphate; common burrows; locally numerous bivalve molds/casts; well laminated 513.8-553.3
– Lag bed, light olive gray (5-Y-5/2), calcareous sand lag bed, fine to coarse quartz sand in a 10 to 30 percent clay matrix, poorly sorted; weakly cemented with calcium carbonate; 1 to 2 percent mica; 1 percent granular phosphate (up to 6 mm); 1 percent very coarse sand; sparse carbonaceous clay clasts (up to 30 mm); common bivalve fragments; sparse shark teeth and bone fragments; massive texture; well indurated 553.3-557.2

(middle Donoho Creek unit)

– Marl, olive gray (5-Y-3/2) to olive black (5-Y-2/1), plastic carbonaceous clay to marl with 5 percent silt, well sorted; 2 to 4 percent mica; weak reaction with hydrochloric acid; common bivalve shells (some preserved in mother-of-pearl); unidentified fossil fragments; very fossiliferous in lower part of interval; well laminated; well compacted 557.2-568.0
– Sandy marl, olive gray (5-Y-3/2), very fine to fine quartz sand and silt in a 20 to 30 percent calcareous clay matrix, well sorted; 4 to 5 percent mica; trace glauconite/chlorite; common bivalve fragments and complete shells; evidence of local heavy bioturbation, otherwise, alternating 10-20 mm beds of calcareous sand and calcareous silty clay below 572.5 feet 568.0-587.5
– Marl, sand beds are dark grayish green (5-GY-4/1) and clayey marl beds are dark gray (N-3), very fine to fine calcareous sand interbedded with beds of clayey marl, well sorted; individual beds are 0.5 to 2.0 feet thick; 2 to 4 percent mica; 1 percent glauconite; abundant megafossil shells (mostly bivalves); sand beds are massive and bioturbated; clayey marl beds are well laminated 587.5-599.2
– Lag bed, olive gray (5-Y-4/1), calcareous lag bed, fine to coarse quartz sand in a 10 to 30 percent clay matrix cemented with calcium carbonate, poorly sorted; 2 to 3 percent mica; 1 percent phosphate grains (up to 7 mm); trace glauconite; cemented sand clasts (up to 20 mm); common shell fragments (mostly bivalves); chaotic texture, especially in lower 4 feet 599.2-606.0

(Bladen Formation)

– Sand, olive gray (5-Y-3/2), fine to medium quartz sand, well to moderately sorted; 2 to 4 percent mica; trace glauconite and rutilated quartz; extremely lignitic from 610 to 611 feet; local thin carbonaceous clayey layers (1 to 2 mm); well bedded with low-angle cross beds 606.0-611.0
– Marl, olive gray (5-Y-3/2), very fine to fine quartz sand (10 percent) in a sticky calcareous clay/marl, well sorted; 5 to 10 percent mica; 5 percent pyritized leaves/wood; common bivalve shells and shell fragments; possible bone fragments; increasing calcium carbonate cementation with depth; poorly laminated with shell fragments; well indurated towards bottom of interval 611.0-623.0

– Shelly limestone, light olive gray (5-Y-5/2), bivalve-rich bed cemented with calcium carbonate, well indurated 623.0-625.4
– Marl, olive gray (5-Y-3/2), very fine to fine quartz sand (10 percent) in a sticky calcareous clay/marl, well sorted; 5 to 10 percent mica; 5 percent pyritized leaves/wood; common bivalve shells and shell fragments; possible bone fragments; poorly laminated with shell fragments; well indurated 625.4-632.5
– Shelly limestone, olive gray (5-Y-4/1), bivalve-rich bed cemented with calcium carbonate, well indurated...632.5-639.1
– Marl, same as marl described above 639.1-642.0
– Shelly limestone, same as shelly limestone described above 642.0-645.8
– Marl, same as marl described above 645.8-651.0
– Shelly limestone, same as shelly limestone described above 651.0-659.2
– Marl, same as marl described above 659.2-669.8

(Coachman Formation)

– Laminated sand and clay, light gray (N-7) to dark gray (N-3), very fine to fine sand in a 10 to 15 percent carbonaceous clay matrix, well sorted; 3 to 4 percent mica; trace glauconite/chlorite; trace very fine lignite; numerous lignite fragments (up to 60 mm) replaced by pyrite; abundant pyritized wood; no calcareous sediments or fossils (as seen in overlying section of core); thinly laminated with carbonaceous clay 669.8-692.9

McQueen Branch aquifer

(Coachman Formation)

– Clayey sand, very light gray (N-8) to light gray (N-7), fine to very coarse quartz sand in a 10 to 15 percent clay matrix, poorly sorted; 2 to 3 percent mica; trace monazite and rutilated quartz; local lignite fragments (up to 70 mm) that are partially replaced by pyrite; 1 percent gravel (up to 8 mm) in thin (0.3 to 0.5 ft) beds; evidence of cross beds; poorly consolidated 692.9-711.2

(Cane Acre Formation)

– Sandy clay, medium light gray (N-6), fine to coarse quartz sand (10 to 20 percent) in a dense waxy clay (70 to 80 percent); 2 to 4 percent mica; 1 percent lignite fragments (up to 50 mm); well bedded 711.2-716.0
– Clayey sand, medium gray (N-5), fine to very coarse quartz sand in a 5 to 10 percent clay matrix, moderately to poorly sorted; 5 percent very fine lignite; 2 percent mica; 1 percent gravel (up to 4 mm); 1 percent pyritized wood; large (up to 40 mm) lignite fragments; low-angle cross beds 716.0-724.2
– Clay, light gray (N-7) to light olive gray (5-Y-6/1) with pale red (5-R-6/2) staining, dense, waxy clay containing 5 to 10 percent fine to very coarse quartz sand; 2 to 5 percent mica; trace rutilated quartz and monazite; evidence of backfilled roots/mud cracks; evidence of slickensides and desiccation cracks 724.2-741.0
– Clayey sand, light gray (N-7) to medium gray (N-5) and olive gray (5-Y-4/1), fine to very coarse quartz sand in 2 to 25 percent clay matrix, poorly sorted; 1 to 2 percent gravel; 2 percent mica; 1 percent rutilated quartz and monazite; trace feldspar and lignite; massive to well bedded; poorly consolidated near top of interval but dense and well indurated below 748 feet 741.0-764.7
– Sandy clay, olive gray (5-Y-4/1), very fine to fine quartz sand (20 percent) in a dense clay matrix (80 percent), well sorted; 2 to 3 percent mica; crudely bedded with evidence of roots/fractures; common carbonaceous matter 764.7-774.2
– Sand, light olive gray (5-Y-6/1), fine to very coarse quartz sand in a 1 to 5 percent clay matrix, poorly sorted; 1 percent gravel; 1 percent rutilated quartz; trace lignite; local thin (30 mm) carbonaceous clay layers; massive, poorly consolidated 774.2-808.0
– Sandy clay, brownish black (5-YR-2/1), fine to coarse quartz sand (20 percent) in a clay matrix (70 percent), poorly sorted; 8 percent lignite fragments (up to 20 mm); 2 percent mica; weak bedding; compact 808.0-809.5
– Sand, sand is light olive gray (5-Y-6/1) to medium gray (N-5) and clay is grayish black (N-2), fine to very coarse quartz sand in a 5 percent clay matrix, poorly sorted; trace rutilated quartz and monazite; local lignite fragments (up to 20 mm); thick (0.5 ft) carbonaceous clay beds; hint of cross bedding; poorly consolidated 809.5-851.3
– Silty clay, dark gray (N-3), very fine to fine quartz sand and silt (15 percent) in carbonaceous clay matrix (85 percent), well sorted; sand occurs in thin (1 to 3 mm) layers; 3 to 4 percent mica; 2 to 3 percent lignite; 1 percent pyritized wood and granular pyrite; well laminated with slightly inclined bedding; compact 851.3-859.5
– Sand, light olive gray (5-Y-6/1) to medium gray (N-5), fine to very coarse quartz sand in a 5 percent clay matrix, poorly sorted; 1 to 2 percent mica; trace rutilated and yellow quartz; abundant lignite and pyritized lignite from 865 to 867 feet; lignite fragments up to 50 mm; weakly bedded 859.5-894.5

(Cape Fear Formation)

– Sandy clay, very light gray (N-8), medium to very coarse quartz sand (20 to 30 percent) in a dense clay matrix (65 to 70 percent), poorly sorted; trace gravel (up to 2 mm); 1 to 2 percent mica; trace rutilated quartz and feldspar; evidence of backfilled roots/fractures; very compact 894.5-900.0
– Sand, olive gray (5-Y-4/1), fine to very coarse quartz sand in a 5 to 15 percent clay matrix, poorly sorted; trace rutilated quartz and lignite; trace gravel (up to 3 mm); moderately to poorly consolidated 900.0-908.0
– Sandy gravel, olive gray (5-Y-4/1), same as described above but with 10 to 15 percent gravel (up to 5 mm) 908.0-910.0
– Sand, light olive gray (5-Y-6/1), fine to very coarse quartz sand in a 5 percent clay matrix, poorly sorted; 1 percent mica; trace rutilated quartz and lignite; sparse gravel; massive texture with only faint signs of cross bedding; sand gets coarser with depth; poorly consolidated 910.0-922.0
– Clayey sand, light olive gray (5-Y-6/1), fine to very coarse quartz sand in a 5 to 10 percent clay matrix, poorly sorted; 2 to 4 percent mica; trace feldspar, rutilated quartz, and lignite; local pyritized nodules (up to 15 mm); grain size increases with depth; very dense and indurated 922.0-933.0
– Sandy gravel, light olive gray (5-Y-6/1), same as described above except with 10 to 15 percent gravel (up to 15 mm) and an increase in feldspar (2 percent) 933.0-936.2
– Clayey sand, light olive gray (5-Y-6/1) to olive gray (5-Y-4/1), fine to very coarse quartz sand in a dense clay matrix, poorly sorted; interval is a clayey sand grading downwards to sand and gravel (fining-upwards sequence); 2 to 3 percent mica; 2 percent gravel (10 mm quartz and 6 mm feldspar) in basal 0.5 feet; 1 percent feldspar; trace rutilated quartz; very poorly bedded; very dense and indurated 936.2-939.5
– Sandy gravel, very light gray (N-8) to medium gray (N-5), same as describe above except basal gravel is 6 mm quartz and 3 mm feldspar 939.5-943.2
– Clayey sand, very light gray (N-8), fine to very coarse quartz sand in a dense clay matrix, poorly sorted; interval is a clayey sand grading downwards to very coarse sand and gravel (fining-upwards sequence); evidence of rooting or filled fractures at top of interval; 2 to 3 percent mica; 2 percent gravel; 1 percent feldspar; trace rutilated quartz; very poorly bedded; dense and indurated 943.2-955.8
– Sandy gravel, light olive gray (5-Y-6/1) with local dark yellowish orange (10-YR-6/6) iron staining, fine to very coarse quartz sand in a 5 to 10 percent clay matrix, poorly sorted; 5 to 10 percent gravel (quartz grains up to 15 mm and feldspar grains up to 14 mm); 2 to 5 percent mica; 1 percent feldspar; massive texture; dense and well indurated 955.8-968.5
– Clayey sand, light olive gray (5-Y-6/1), fine to medium quartz sand, moderately sorted; 2 to 4 percent mica; 1 percent feldspar; trace rutilated quartz; massive texture; dense and well indurated 968.5-970.5
– Sandy gravel, medium light gray (N-6), fine to very coarse quartz sand and gravel, poorly sorted; gravel 10 to 15 percent; 2 to 4 percent mica; 1 percent feldspar; trace rutilated quartz; faint evidence of cross bedding; dense and well indurated 970.5-977.0

Gramling confining unit

(Cape Fear Formation)

– Sandy gravel, greenish gray (5-GY-6/1), fine to coarse quartz sand and gravel in a 5 to 10 percent clay matrix, moderately sorted; 3 to 4 percent mica; 1 percent feldspar (up to 8 mm); trace rutilated quartz; well indurated by silica (?) cement 977.0-998.5
– Silty clay, greenish gray (5-GY-6/1) with moderate red (5-R-5/4) and dark yellowish orange (10-YR-6/6) staining, silt (10 percent) in a crumbly, dry clay matrix, well sorted; 4 to 10 percent mica; extensive iron staining; well laminated; slickensided fractures; root structures; dense and compact 998.5-1000.0
– Clayey sand, olive gray (5-Y-4/1), fine to very coarse quartz sand in a 5 to 10 percent clay matrix, poorly sorted; 5 to 10 percent mica (local 0.1 ft beds are 40 to 50 percent mica); 1 percent gravel (up to 12 mm); 1 percent feldspar; well indurated and dense 1000.0-1003.0
– Sandy clay, grayish green (10-GY-5/2) with dark yellowish orange (10-YR-6/6) staining, fine to medium quartz sand in a 5 to 10 percent clay matrix, moderately sorted; grading downwards to fine to very coarse sand and gravel; 5 to 10 percent mica (local 0.1 ft beds are 40 to 50 percent mica); gravel up to 12 mm (quartz) and 4 mm (feldspar); local iron staining; massive and well indurated 1003.0-1006.0
– Sandy gravel, olive gray (5-Y-4/1), fine to very coarse quartz sand in a 5 to 10 percent clay matrix, poorly sorted; 1 percent gravel (up to 12 mm); 5 to 10 percent mica (local thin beds contain 20 to 25 percent very coarse mica); trace rutilated and yellow quartz; massive texture; well indurated 1006.0-1011.5
– Sandy clay, brownish black (5-YR-2/1) to brownish gray (5-YR-4/1), fine to medium quartz sand (40 percent) in a waxy, carbonaceous clay matrix (60 percent), moderately sorted; 4 to 6 percent mica; 1 percent feldspar; trace rutilated quartz; evidence of clay- filled roots/fractures; well laminated 1011.5-1013.5

– Sandy gravel, medium gray (N-5) to olive gray (5-Y-4/1) with moderate yellowish brown (10-YR-5/4) staining, fine to very coarse quartz sand and gravel, poorly sorted; 1 percent feldspar; trace rutilated quartz; gravel up to 15 mm as rutilated quartz, 8 mm as smoky quartz, and 5 mm as feldspar; local iron staining; crude bedding 1013.5-1023.4
– Sandy clay, grayish green (10-GY-5/2), fine to medium quartz sand (35 percent) in a clay matrix (60 percent), well sorted; 1 to 2 percent mica; 1 percent feldspar; trace rutilated quartz; well laminated ... 1023.4-1025.0
– Sandy gravel, grayish green (10-GY-5/2), fine to very coarse quartz sand and gravel in a clay matrix 5 to 15 percent clay matrix, poorly sorted; gravel up to 25 mm as quartz and 6 mm as feldspar; 1 to 2 percent mica; 1 percent feldspar; trace rutilated quartz; massive to crudely bedded 1025.0-1031.8
– Clayey sand, light olive gray (5-Y-6/1), fine to very coarse quartz sand in a 5 to 10 percent clay matrix, poorly sorted; 5 to 10 percent mica (up to 8 mm); 1 percent gravel (up to 7 mm as rutilated quartz and up to 25 mm as smoky quartz); massive to poorly bedded; indurated 1031.8-1034.0
– Sandy gravel, light olive gray (5-Y-6/1) to grayish green (10-GY-5/2), fine to very coarse quartz sand and gravel, poorly sorted; 10 percent gravel (up to 30 mm as smoky quartz, 19 mm as rutilated quartz, 16 mm as white quartz, and 3 mm as feldspar); sparse slate- belt foliated quartz/rock pebbles; 1 to 2 percent mica; 1 percent feldspar; common clay clasts in lower 5 feet; trace garnet and lignite (up to 30 mm); weakly bedded; compact/cemented 1034.0-1055.5
– Clayey sand, greenish gray (5-G-5/2), fine to coarse quartz sand in a clay matrix, poorly sorted; 2 to 3 percent mica; trace blue quartz, rutilated quartz, garnet, and feldspar; massive; semi-consolidated to well indurated 1055.5-1058.0
– Sandy gravel, greenish gray (5-G-5/2), fine to very coarse quartz sand and gravel, poorly sorted; gravel up to 8 mm as smoky quartz, 10 mm as slate belt quartz/rock pebbles, and 3 mm as feldspar; 2 to 3 percent mica; trace blue quartz, rutilated quartz, garnet, and feldspar; massive; semi-consolidated to well indurated 1058.0-1064.7
– Clayey sand, grayish green (10-GY-5/2), fine to coarse quartz sand in a 25 to 30 percent clay matrix, poorly sorted; 3 to 4 percent mica; 1 percent feldspar; well indurated 1064.7-1067.0
– Sandy gravel, grayish green (10-GY-5/2), fine to very coarse quartz sand and gravel, poorly sorted; gravel up to 30 mm as smoky quartz, 20 mm as rutilated quartz, and 6 mm as feldspar; 3 to 4 percent mica; 1 percent feldspar; massive texture; well indurated 1067.0-1073.0
– Sandy clay, light olive gray (5-Y-6/1) with local dark yellowish orange (10-YR-6/6) iron staining, fine to medium quartz sand in a 10 to 20 percent clay matrix, well sorted; 2 to 3 percent mica; 1 percent feldspar; trace garnet; faint bedding disrupted by backfilled burrows/roots; bedding appears undulatory and local iron staining is present; well indurated 1073.0-1074.9
– Sandy gravel, grayish green (5-G-5/2) with local dark yellowish orange (10-YR-6/6) iron staining, fine to very coarse quartz sand and gravel, poorly sorted; gravel up to 7 mm as smoky quartz and 5 mm as feldspar; 2 to 3 percent mica; 1 percent feldspar; trace garnet; massive texture; well indurated 1074.9-1078.0
– Sandy clay, light olive gray (5-Y-6/1) with local dark yellowish orange (10-YR-6/6) iron staining, fine to medium quartz sand in a 10 to 20 percent clay matrix, well sorted; faint bedding disrupted by backfilled burrow/roots; well indurated 1078.0-1080.5
– Sandy gravel, grayish green (5-G-5/2), fine to very coarse quartz sand and gravel, poorly sorted; common feldspar; local metamorphic rock fragments and clay clasts; mottled; massive to crudely bedded; poorly consolidated to indurated 1080.5-1116.5

Piedmont Hydrogeologic Province
(Redbeds)
– Sandstone, moderate reddish brown (10-R-4/6) mottled with light greenish gray (5-G-8/1), mudstone to pebbly mudstone to conglomeratic sandstone, very poorly sorted; highly fractured; slickensided surfaces; pebbles are quartz, feldspar, and a variety of metamorphic rock fragments; conglomeratic in lower 6 feet; massive to crudely bedded; indurated 1116.5-1138.0

Missing intervals (ft)

8.3-10.0	495.6-498.0
11.6-15.0	507.2-508.0
18.1-20.0	516.2-518.0
23.1-25.0	522.4-528.0
26.1-30.0	534.2-538.0
34.5-35.0	547.2-548.0
37.8-40.0	576.7-578.0
44.3-45.0	596.5-598.0
53.3-55.0	606.4-608.0
58.0-60.0	614.4-620.0
60.0-64.4	635.4-638.0
64.4-65.0	645.8-648.0
74.7-75.0	655.0-658.0
84.5-85.0	667.6-668.0
85.9-88.0	670.0-678.0
94.8-98.0	685.2-688.0
101.4-104.5	694.2-695.5
105.1-108.0	702.0-703.0
109.3-113.0	707.2-709.6
116.2-118.5	717.4-721.6
127.5-128.0	743.0-748.0
136.8-138.0	757.5-758.0
157.8-158.0	765.5-768.0
162.5-168.0	775.2-778.0
172.5-173.0	782.3-788.0
186.6-188.0	795.6-797.0
197.6-198.0	806.4-808.0
203.0-208.0	824.5-828.0
216.9-218.0	831.9-838.0
227.1-228.0	847.8-848.0
236.3-238.0	851.3-858.0
245.2-248.0	867.2-868.0
254.4-258.0	876.3-878.0
262.2-268.0	886.9-888.0
274.4-278.0	896.4-897.0
282.4-288.0	906.1-908.0
291.2-298.0	916.3-918.0
303.3-308.0	927.0-928.0
311.8-318.0	937.6-938.0
347.1-348.0	947.0-948.0
357.9-358.0	979.4-987.0
366.2-368.0	989.5-994.0
376.2-378.0	994.5-998.0
384.1-388.0	1007.8-1008.0
395.4-398.0	1029.5-1030.5
407.4-408.0	1034.2-1034.7
415.1-417.0	1047.8-1048.0
422.4-423.0	1056.5-1058.0
425.9-428.0	1070.3-1071.5
435.0-438.0	1077.5-1078.0
447.4-448.0	1107.9-1108.0
467.2-468.0	1111.3-1116.5
477.5-478.0	1119.5-1129.0
487.5-488.0	1131.2-1132.0

Well: ORG-393
Latitude: 33 30 29
Longitude: 80 51 54
Elevation: 253 feet
Geology and core description by Dr. David C. Prowell (USGS)

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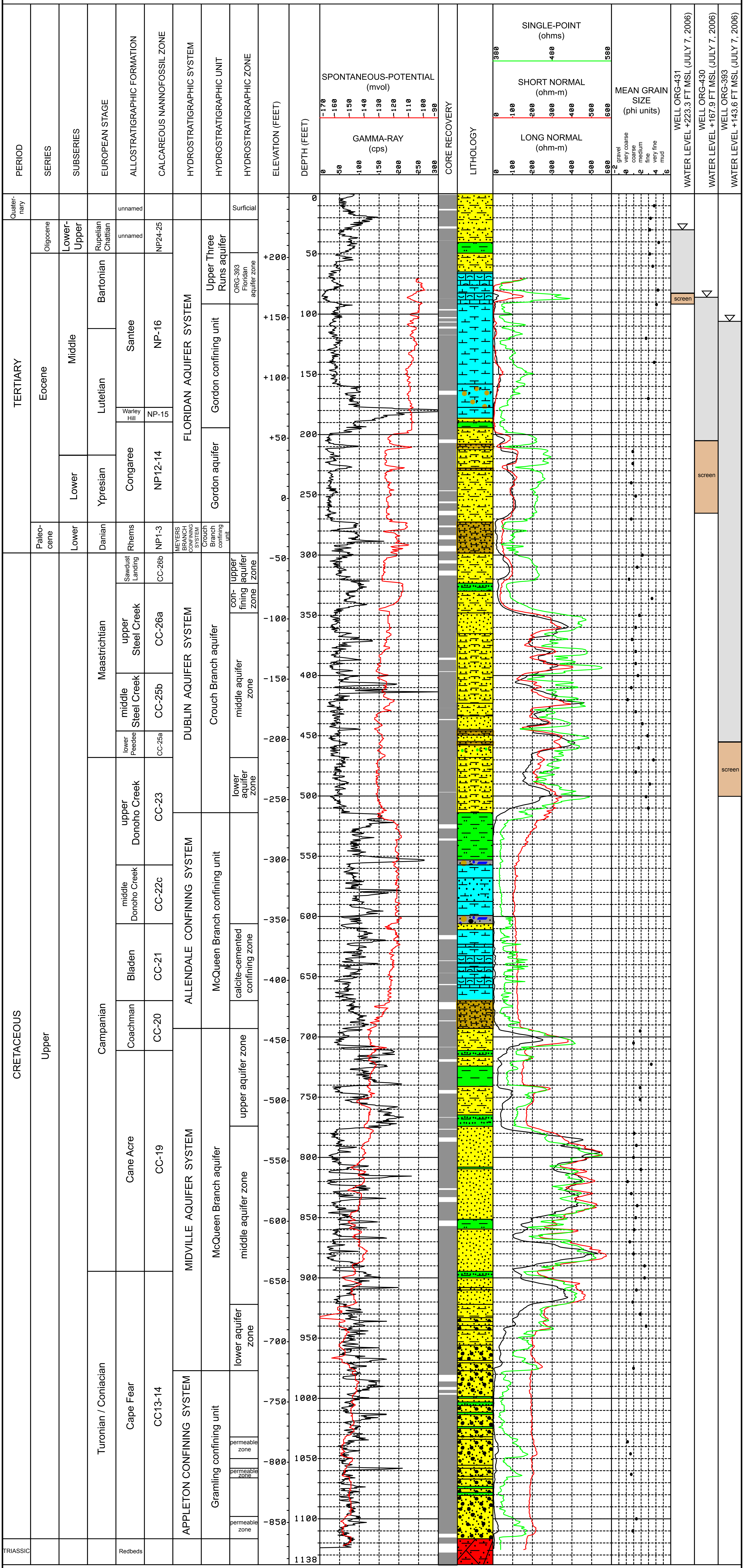
Plate 1: Stratigraphy, geophysical logs, and lithology of core hole ORG-393



LITHOLOGY

- Clayey sand
- Interbedded sand and clay
- Clay
- Silty clay
- Sandy clay
- Sand and gravel
- Marl
- Sand
- Redbeds
- Shelly limestone
- Glauconitic sand
- Phosphatic marl
- Unconformity lag
- Laminated sand and clay
- Sandy marl

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Plate 2: Hydrogeologic section A-A'

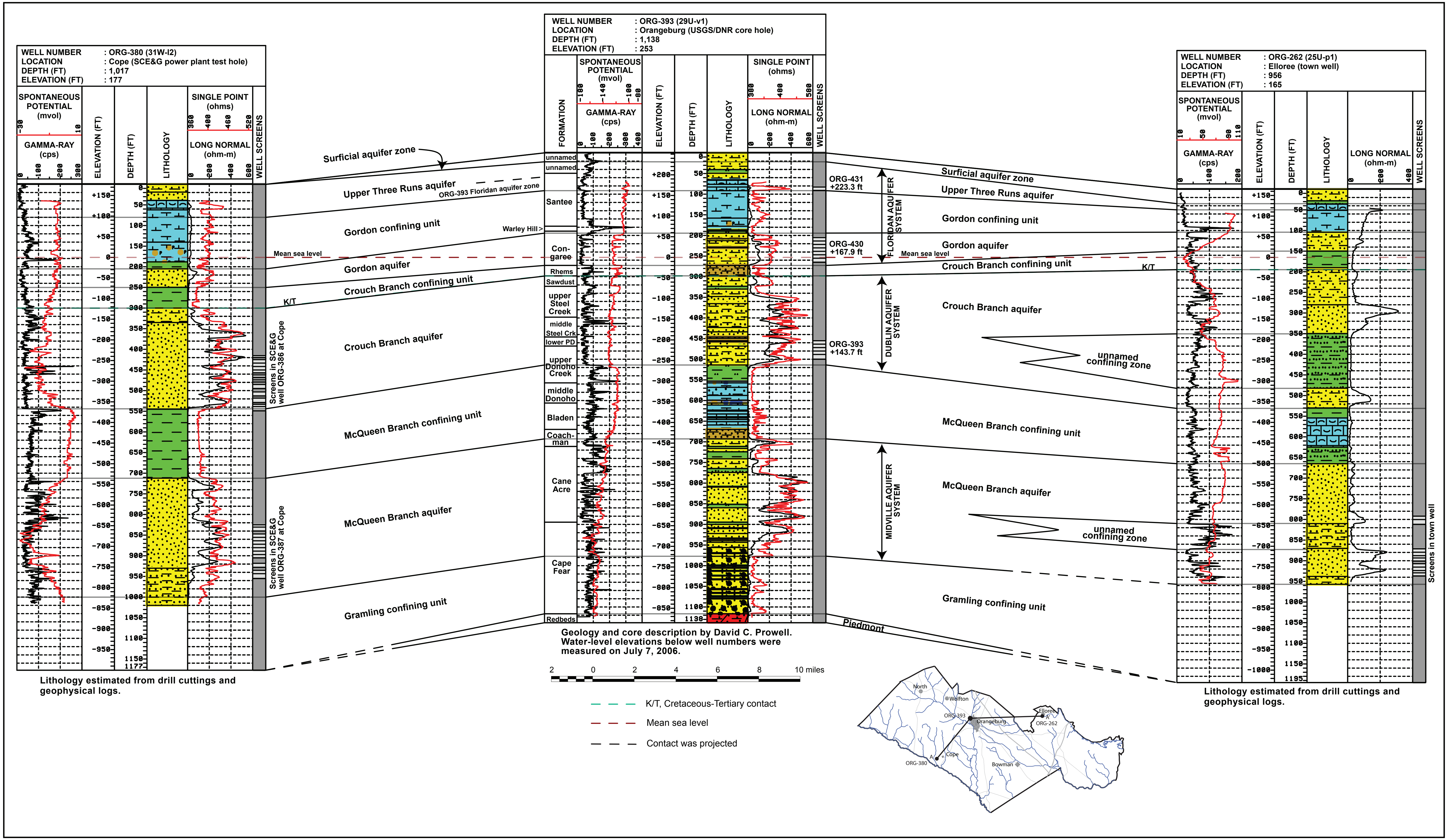

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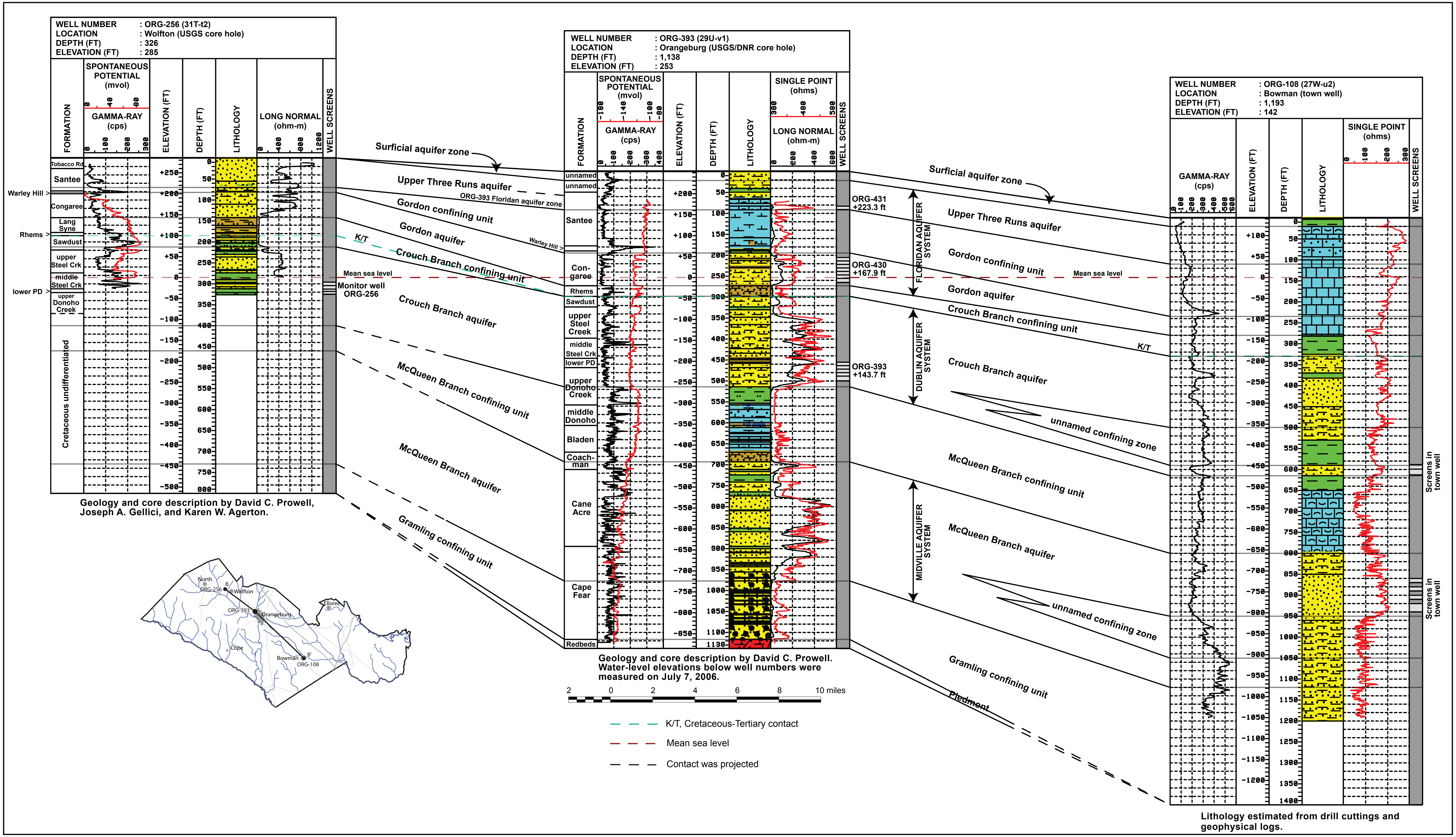
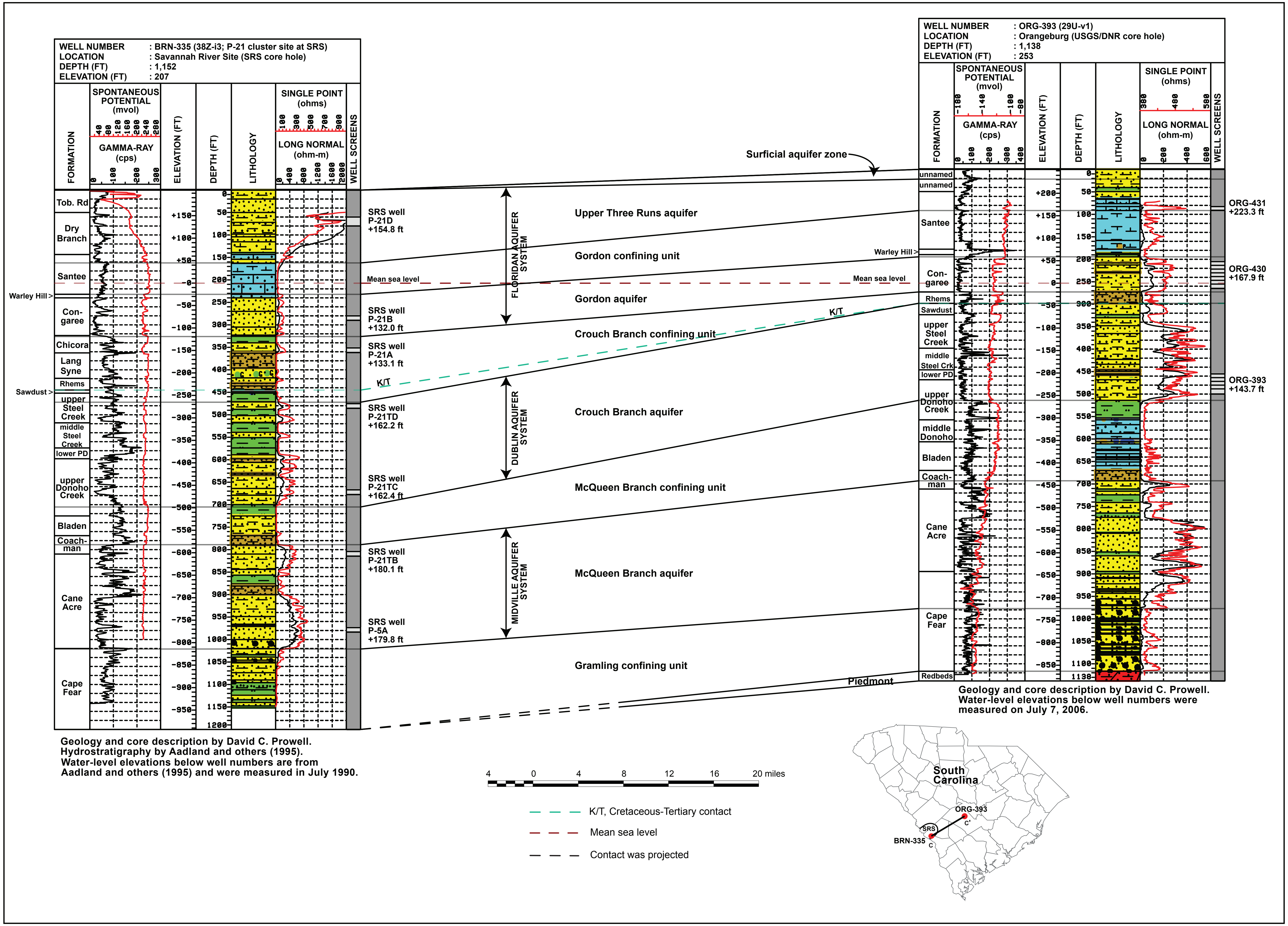
Plate 3: Hydrogeologic section B-B'




WELL NUMBER : BRN-335 (38Z-i3; P-21 cluster site at SRS)
LOCATION : Savannah River Site (SRS core hole)
DEPTH (FT) : 1,152
ELEVATION (FT) : 207
FORMATION
SPONTANEOUS POTENTIAL (mvol)
GAMMA-RAY (cps)
ELEVATION (FT)
DEPTH (FT)
LITHOLOGY
SINGLE POINT (ohms)
LONG NORMAL (ohm-m)
WELL SCREENS
Tob. Rd
Dry Branch
Santee
Warley Hill >
Con-garee
Chicora
Lang Syne
Rhems
Sawdust >
upper Steel Creek
middle Steel Creek
lower PD
upper Donoho Creek
Bladen
Coach-man
Cane Acre
Cape Fear
SRS well P-21D +154.8 ft
SRS well P-21B +132.0 ft
SRS well P-21A +133.1 ft
SRS well P-21TD +162.2 ft
SRS well P-21TC +162.4 ft
SRS well P-21TB +180.1 ft
SRS well P-5A +179.8 ft
Mean sea level
K/T
Surficial aquifer zone
Upper Three Runs aquifer
Gordon confining unit
Gordon aquifer
Crouch Branch confining unit
Crouch Branch aquifer
McQueen Branch confining unit
McQueen Branch aquifer
Gramling confining unit
Piedmont
FLORIDAN AQUIFER SYSTEM
DUBLIN AQUIFER SYSTEM
MIDVILLE AQUIFER SYSTEM
WELL NUMBER : ORG-393 (29U-v1)
LOCATION : Orangeburg (USGS/DNR core hole)
DEPTH (FT) : 1,138
ELEVATION (FT) : 253
unnamed
unnamed
Santee
Warley Hill >
Con-garee
Rhems
Sawdust
upper Steel Creek
middle Steel Crk
lower PD
upper Donoho Creek
middle Donoho
Bladen
Coach-man
Cane Acre
Cape Fear
Redbeds
ORG-431 +223.3 ft
ORG-430 +167.9 ft
ORG-393 +143.7 ft
Geology and core description by David C. Prowell.
Water-level elevations below well numbers were measured on July 7, 2006.
Geology and core description by David C. Prowell.
Hydrostratigraphy by Aadland and others (1995).
Water-level elevations below well numbers are from Aadland and others (1995) and were measured in July 1990.
4 0 4 8 12 16 20 miles
K/T, Cretaceous-Tertiary contact
Mean sea level
Contact was projected
South Carolina
ORG-393
C'
SRS
BRN-335
C